CDFA FERTILIZER RESEARCH AND EDUCATION PROGRAM

February 1, 2002 to September 30, 2005

Final Report

January 31, 2007

Development of BMPs for Fertilizing Lawns to Optimize Plant Performance and Nitrogen Uptake While Reducing the Potential for Nitrate Leaching

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CHAPTER 1: TITLE, STATEMENT OF OBJECTIVE, AND EXECUTIVE SUMMARY

FINAL REPORT – February 1, 2002 to September 30, 2005

Development of BMPs for Fertilizing Lawns to Optimize Plant Performance and Nitrogen Uptake While Reducing the Potential for Nitrate Leaching

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Statement of Objective

The problem addressed by this project is nitrate-nitrogen (NO_3^--N) contamination of groundwater caused by fertilization of the approximate 679,426 acres of residential yards in California. Nitrate contamination of groundwater is an extensive problem in California. Fertilization of agriculture land and urban landscapes are a major source of NO_3^--N contamination. Residential yards are the largest component of urban landscapes and lawns are the largest component of residential yards. Thus, a project involving the development of best management practices (BMPs) for fertilizing lawns to optimize plant performance and N uptake while reducing the potential for NO_3^--N leaching focuses on a major urban source of NO_3^--N contamination of groundwater. Since the project is on tall fescue, the most widely used lawngrass in California, the impact of this project is on a statewide basis. Including research sites in both southern and northern California (on mature and newly established tall fescue plots, respectively) provides a broader context in which to interpret the results. The objectives of this project are listed below.

1. Evaluate the annual N rate and source on tall fescue to determine which treatments optimize plant performance and N uptake while reducing the potential for NO_3^--N leaching.

2. Quantify the effect of N fertilizer rate and source on: visual turfgrass quality and color; clipping yield, tissue N concentration, and N uptake; and concentration of NO_3^--N in leachate at a depth below the rootzone.

3. Develop BMPs for the fertilization under representative irrigation practices of lawns to optimize plant performance and N uptake while reducing the potential for NO_3^--N leaching.

4. Conduct outreach activities, including oral presentations and trade journal publications, emphasizing the importance of the BMPs and how to carry out these practices for N fertilization of lawns.

Executive Summary

Development of BMPs for Fertilizing Lawns to Optimize Plant Performance and Nitrogen Uptake While Reducing the Potential for Nitrate Leaching

The problem addressed by this project is nitrate nitrogen (NO_3^--N) contamination of groundwater caused by fertilization of the approximate 679,426 acres of residential yards in California. Nitrate contamination of groundwater is an extensive problem in California. Fertilization of agriculture land and urban landscapes are a major source of NO_3^--N contamination. Residential yards are the largest component of urban landscapes and lawns are the largest component of residential yards. Thus, a project involving the development of best management practices (BMPs) for fertilizing lawns to optimize plant performance and N uptake while reducing the potential for NO_3^--N leaching focuses on a major urban source of NO_3^--N contamination of groundwater. Since the project is on tall fescue, the most widely used lawngrass in California, the impact of this project is on a statewide basis. Including research sites in both southern and northern California provides a better context in which to interpret the results.

Petrovic prepared a review paper entitled "The fate of nitrogenous fertilizers applied to turfgrass." He summarized 11 papers on NO_3^--N leaching from fertilizers applied to turfgrass and he concluded that leaching of fertilizer N applied to turfgrass has been shown to be highly influenced by soil texture; N source, rate, and timing; and irrigation/rainfall. If a significantly higher than normal rate of a soluble N source is applied to a sandy turfgrass site that is highly irrigated, significant NO_3^--N leaching could occur. However, limiting irrigation to only replace moisture used by the plant, using slow-release N sources, and using less sandy soils will significantly reduce or eliminate NO_3^--N leaching from turfgrass sites. Other research has shown that there is a negligible chance of NO_3^--N leaching from turf. However, these findings are normally conditional as follows: water soluble fertilizers are not applied in excess; sandy soils are not heavily irrigated; turf is well maintained using standard agronomic practices including judicious use of fertilizers and irrigation; the turfgrass is not immature and the soil is not disturbed such as during establishment; and root absorption is not low because of dormancy, stress, or because of unhealthy turfgrass. In reality, home-lawn owners probably cause NO_3^--N contamination of groundwater because they do not meet all the conditions that are required to not cause NO_3^--N contamination of groundwater.

The objectives of this project, involving mature and newly established turfgrass plots, are to 1) evaluate the annual N rate and source on tall fescue to determine which treatments optimize plant performance and N uptake while reducing the potential for NO_3^--N leaching; 2) quantify the effect of N fertilizer rate and source on visual turfgrass quality and color, clipping yield, tissue N concentration and N uptake, and concentration of NO_3^--N in leachate at a depth below the rootzone; 3) develop BMPs for lawns under representative irrigation practices to optimize plant performance and N uptake while reducing the potential for NO_3^--N leaching; and 4) conduct outreach activities, including oral presentations and trade journal publications, emphasizing the importance of the BMPs and how to carry out these practices for N fertilization of lawns.

This project was conducted on plots located at the UC Riverside (UCR) Turfgrass Research Facility and at the field facilities of the UC Davis (UCD) Department of Plant Sciences. The UCR plot was seeded to Marathon III tall fescue in Apr. 1996 and was a mature, uniform stand. The plot at UCD was sodded to Marathon III tall fescue in Oct. 2002. At both sites the experimental design was a randomized complete block (RCB) design with N source and rate treatments arranged in a 4 × 3 factorial. The N sources included ammonium nitrate, a fast-release, water soluble N source; Polyon, a slow-release, polymer-coated N source; Milorganite, a slow-release, natural organic N source; and Nutralene, a slow-release, water insoluble, methylene ureas N source. Each fertilizer was applied at the annual N rate of 4.0, 6.0, and 8.0 lb/1000 ft^2. Nitrogen treatments were applied to 5- × 7-ft plots by hand to ensure accuracy. The plots were irrigated at 110% ET_o and the amount of irrigation was determined each week based on the previous 7-d cumulative ET_o, obtained from an on-site CIMIS station. There were three irrigation events per week. The plot was mowed one time per week using a walk-behind, rotary mower set at 1.5 inch mowing height; clippings were collected. Measurements included visual turfgrass quality and color ratings, clipping yield, tissue N concentration and N uptake, and NO_3^--N concentration of soil water below the rootzone. Treatments and measurements were conducted from Oct. 2002 to Oct. 2004 at UCR and from May 2003 to Dec. 2005 at UCD.

Based on data collected during this study, several BMPs were developed and are listed below.

1. Minimalist irrigation reduces the potential for nitrate leaching. However, sufficient irrigation is needed to promote healthy turfgrass.

2. An annual N rate of 4 to 6 lb/1000 ft^2 produces an acceptable to good quality tall fescue lawn. Higher rates are not necessary and increase the risk of nitrate leaching.

3. Slow-release N sources (Nutralene, Milorganite, and Polyon) cause less nitrate leaching than a fast-release N source (ammonium nitrate).

4. The amount of nitrate leaching from a fast-release N source can be drastically reduced if N rates of individual applications do not exceed 1.0 to 1.5 lb/1000 ft^2.

During this project, there were 20 outreach activities, so we believe the information related to the topic was well conveyed. During the second half of the project, the topic of BMPs was emphasized. Adoption of BMPs can occur over time if the information continues to be conveyed to the general public.

CHAPTER 2: ANNUAL WORK DESCRIPTIONS AND RELATED INFORMATION

Work Description: YEAR 1 (February to December 2002)

(Taken from 2002 Annual Report)

YEAR 1: February to December 2002 at UC Riverside

Task 1: Implement treatments according to protocol described in Table 1 and Fig. 1.

The purpose of this task was to apply N fertility treatments in an accurate method. The experimental design is a RCB design with N treatments arranged in a 4×3 factorial. There are four N sources and three rates. Each fertilizer was applied at the same three rates. Nitrogen treatments were applied to 5.0- $\times$ 7.0-ft plots by hand to ensure accuracy. A no nitrogen check treatment also was included. Date of fertilizer application was held constant (N source and rate varied) in order to facilitate N uptake calculations and comparisons among N treatments. Ideally, the treatment design and data collection will result in a greater understanding of the influence of N treatments on tall fescue performance and concentration of NO_3^--N in soil water at a depth below the rootzone. Initial N fertility treatments were applied on 15 October 2002.

Task 2: Implement data collection according to protocol described in Table 2.

The purpose of this task was to quantify adequately, via sound methodology, the treatment effects on visual appearance, growth (clipping yield), and N uptake of tall fescue, along with NO_3^--N concentration in soil water below the rootzone. Since weather conditions also influence plant and soil measurements, detailed weather data were collected, and aided in data interpretation. Proper measurements were collected in order to test adequately the significance of treatment effects.

Task 3: Implement research plot management according to protocol described in Table 3.

The primary purpose of this task was to ensure that representative tall fescue is maintained under consistent conditions for the duration of the study. This practice helps to discern treatment effects. A second purpose of this task was to ensure accurate and consistent irrigation by frequent irrigation-system monitoring.

Task 4: Implement outreach activities.

The purpose of this task was to present one oral presentation and prepare two popular journal articles concerning the background and objectives of the research project. Preliminary data from the research project may also be included. The presentation was given at the UCR Turfgrass and Landscape Management Field Day. The task products were one oral presentation and two popular journal articles.

> **Subtask 4.1:** Identify target audience, plan and prepare a presentation, identify potential meetings and dates where the presentation may be delivered.
>
> **Subtask 4.2:** Present one oral presentation.
>
> **Subtask 4.3:** Prepare two popular journal articles.

Task 5: Prepare interim and annual reports.

Reports detailed the progress of Tasks 1 to 4. These reports provided the tool for evaluating the activity for the first 11 months of this project.

YEAR 1: September to December 2002 at UC Davis

Task 0: Establish a Marathon III tall fescue research plot.

A research plot was prepared for this research project. The soil was rototilled to a minimum of 6 inches followed by the construction of a below-ground irrigation system having a distribution uniformity of not less then 0.85. The plot was leveled, firmed and sodded to Marathon III tall fescue.

Task 5: Prepare an annual report.

An annual report, including the progress of Task 0, was submitted to CDFA-FREP.

Revised Work Plan: YEAR 2 (January to December 2003)

(Taken from 2002 Annual Report)

YEAR 2: January to December 2003 at UC Riverside

Task 1: Implement treatments according to protocol described in Table 1 and Fig. 1.

The purpose of this task is to apply N fertility treatments in an accurate method. The experimental design is a RCB design with N treatments arranged in a 4×3 factorial. There are four N sources and three N rates. Each fertilizer is applied at the same three rates. Nitrogen treatments are applied to 5.0- $\times$ 7.0-ft plots by hand to ensure accuracy. A no nitrogen check treatment also was included. Date of fertilizer application was held constant (N source and rate varied) in order to facilitate N uptake calculations and comparisons among N treatments. Ideally, the treatment design and data collection will result in a greater understanding of the influence of N treatments on tall fescue performance and concentration of NO_3^--N and NH_4^+-N in soil water at a depth below the rootzone.

An interim and annual report, including the progress of Task 1, will be submitted to CDFA-FREP on 31 July 2003 and 31 January 2004, respectively.

Month of initiation: 1/03
Month of completion: 12/03

Task 2: Implement data collection according to protocol described in Table 2.

The purpose of this task is to quantify adequately, via sound methodology, the treatment effects on visual appearance, growth (clipping yield), and N uptake of tall fescue, along with NO_3^--N and NH_4^+-N concentration in soil water below the rootzone and in the soil profile. Since weather conditions also influence plant and soil measurements, detailed weather data are being collected, and may aid in data interpretation. Ideally, proper measurements will be collected in order to test adequately the significance of treatment effects.

An interim and annual report, including the progress of Task 2, will be submitted to CDFA-FREP on 31 July 2003 and 31 January 2004, respectively.

Month of initiation: 1/03
Month of completion: 12/03

Task 3: Implement research plot management according to protocol described in Table 3.

The primary purpose of this task is to ensure representative tall fescue that is maintained under consistent conditions for the duration of the study. This practice will help discern treatment effects. A second purpose of this task is to ensure accurate and consistent irrigation by frequent irrigation-system monitoring.

An interim and annual report, including the progress of Task 3, will be submitted to CDFA-FREP on 31 July 2003 and 31 January 2004, respectively.

Month of initiation: 1/03

Month of completion: 12/03

Task 4: Implement outreach activities.

The purpose of this task is to prepare one popular journal article concerning the background and objectives of the research project. Data from the research project may also be included. The task product will be one popular journal article.

An interim and annual report, including the progress of Task 4, will be submitted to CDFA-FREP on 31 July 2003 and 31 January 2004, respectively.

Month of initiation: 1/03
Month of completion: 12/03

Subtask 4.1: Prepare one popular journal article. Complete by 12/03.

Task 5: Prepare interim and annual reports.

Reports will detail the progress of Tasks 1 to 4. These reports will provide the tool for evaluating the activity for the second 12 months of this project. Interim report will be submitted 31 July 2003 while the annual report will be submitted 31 January 2004.

Month of initiation: 5/03
Month of completion: 1/04

YEAR 2: January to December 2003 at UC Davis

Task 1: Implement treatments according to protocol described in Table 1 and Fig. 2.

The purpose of this task is to apply N fertility treatments in an accurate method. The experimental design is a RCB design with N treatments arranged in a 4×3 factorial. There are four N sources and three N rates. Each fertilizer is applied at the same three rates. Nitrogen treatments are applied to 5.0- $\times$ 7.0-ft plots by hand to ensure accuracy. A no nitrogen check treatment also was included. Date of fertilizer application was held constant (N source and rate varied) in order to facilitate N uptake calculations and comparisons among N treatments. Ideally, the treatment design and data collection will result in a greater understanding of the influence of N treatments on tall fescue performance and concentration of NO_3^--N and NH_4^+-N in soil water at a depth below the rootzone. Initial fertilizer treatments were applied on 15 May 2003.

An interim and annual report, including the progress of Task 1, will be submitted to CDFA-FREP on 31 July 2003 and 31 January 2004, respectively.

Month of initiation: 5/03
Month of completion: 12/03

Task 2: Implement data collection according to protocol described in Table 2.

The purpose of this task is to quantify adequately, via sound methodology, the treatment effects on visual appearance, growth (clipping yield), and N uptake of tall fescue, along with NO_3^--N and NH_4^+-N concentration in soil water below the rootzone. Since weather conditions also influence plant and soil measurements, detailed weather data are being collected, and may aid in data interpretation. Ideally, proper measurements will be collected in order to test adequately the significance of treatment effects.

An interim and annual report, including the progress of Task 2, will be submitted to CDFA-FREP on 31 July 2003 and 31 January 2004, respectively.

Month of initiation: 8/03
Month of completion: 12/03

Task 3: Implement research plot management according to protocol described in Table 3.

The primary purpose of this task is to ensure representative tall fescue that is maintained under consistent conditions for the duration of the study. This practice will help discern treatment effects. A second purpose of this task is to ensure accurate and consistent irrigation by frequent irrigation-system monitoring.

An interim and annual report, including the progress of Task 3, will be submitted to CDFA-FREP on 31 July 2003 and 31 January 2004, respectively.

Month of initiation: 1/03
Month of completion: 12/03

Task 4: Implement outreach activities.

The purpose of this task is to present one oral presentation and one popular journal article concerning the background and objectives of the research project. Data from the research project may also be included. The presentation will occur at either general grower meetings or at specially planned meetings and/or tours. The task products will be one oral presentation and one popular journal article.

An interim and annual report, including the progress of Task 4, will be submitted to CDFA-FREP on 31 July 2003 and 31 January 2004, respectively.

Month of initiation: 1/03
Month of completion: 12/03

> **Subtask 4.1:** Identify target audience, plan and prepare a presentation, identify potential meetings and dates where the presentation may be delivered. Complete by 4/03.
>
> **Subtask 4.2:** Present one oral presentation. Complete by 12/03.
>
> **Subtask 4.3:** Prepare one popular journal article. Complete by 12/03.

Task 5: Prepare interim and annual reports.

Reports will detail the progress of Tasks 1 to 4. These reports will provide the tool for evaluating the activity for both the second 12 months of this project and the project as a whole. Interim report will be submitted 31 July 2003 while the annual report will be submitted 31 January 2004.

Month of initiation: 5/03
Month of completion: 1/04

Revised Work Plan: YEAR 3 (January to December 2004)

(Taken from 2003 Annual Report)

YEAR 3: January to December 2004 at UC Riverside

Task 1: Implement treatments according to protocol described in Table 1 and Fig. 1.

The purpose of this task is to apply N fertility treatments in an accurate method. The experimental design is a RCB design with N treatments arranged in a 4×3 factorial. There are four N sources and three N rates. Each fertilizer is applied at the same three rates. Nitrogen treatments will be applied to 5.0- $\times$ 7.0-ft plots by hand to ensure accuracy. A no nitrogen check treatment is also included. Date of fertilizer application was held constant (N source and rate varied) in order to facilitate N uptake calculations and comparisons among N treatments. Ideally, the treatment design and data collection will result in a greater understanding of the influence of N treatments on tall fescue performance and concentration of NO_3^--N and NH_4^+-N in soil water at a depth below the rootzone. The last N fertility treatment application date will be made on 15 August 2004.

An interim and annual report, including the progress of Task 1, will be submitted to CDFA-FREP on 31 July 2004 and 31 January 2005, respectively.

Month of initiation: 1/04
Month of completion: 8/04

Task 2: Implement data collection according to protocol described in Table 2.

The purpose of this task is to quantify adequately, via sound methodology, the treatment effects on visual appearance, growth (clipping yield), and N uptake of tall fescue, along with NO_3^--N and NH_4^+-N concentration in soil water below the rootzone and in the soil profile. Since weather conditions also influence plant and soil measurements, detailed weather data will be collected, and may aid in data interpretation. Ideally, proper measurements will be collected in order to test adequately the significance of treatment effects. The 24-month period of field data collection will end on approximately 15 October 2004. However, the process of data development will continue (tissue preparation for TKN analysis and data organization, analysis, and summary).

An interim and annual report, including the progress of Task 2, will be submitted to CDFA-FREP on 31 July 2004 and 31 January 2005, respectively.

Month of initiation: 1/04
Month of completion: 12/04

Task 3: Implement research plot management according to protocol described in Table 3.

The primary purpose of this task is to ensure representative tall fescue that is maintained under consistent conditions for the duration of the study. This practice will help discern treatment effects. A second purpose of this task is to ensure accurate and consistent irrigation by frequent irrigation-system monitoring. The 24-month period of field data collection will end on approximately 15 October 2004.

An interim and annual report, including the progress of Task 3, will be submitted to CDFA-FREP on 31 July 2004 and 31 January 2005, respectively.

Month of initiation: 1/04
Month of completion: 10/04

Task 4: Implement outreach activities. (Please note there will be one outreach activity in 2004 and two in 2005)

The purpose of this task is to present one oral presentation concerning the background and objectives of the research project. Data from the research project will also be included. The presentation will occur at either general grower meetings, at the UCR Turfgrass Research Conference and Field Day, or at specially planned meetings and/or tours. The task product will be one oral presentation.

An interim and annual report, including the progress of Task 4, will be submitted to CDFA-FREP on 31 July 2004 and 31 January 2005, respectively.

Month of initiation: 1/04
Month of completion: 12/04

> **Subtask 4.1:** Identify target audience, plan and prepare a presentation, identify potential meetings and dates where the presentation may be delivered. Complete by 4/04.
>
> **Subtask 4.2:** Present one oral presentation. Complete by 12/04.

Task 5: Prepare interim and annual reports.

Reports will detail the progress of Tasks 1 to 4. These reports will provide the tool for evaluating the activity for the third 12 months of this project. Interim report will be submitted 31 July 2004 while the annual report will be submitted 31 January 2005.

Month of initiation: 5/04
Month of completion: 1/05

YEAR 3: January to December 2004 at UC Davis

Task 1: Implement treatments according to protocol described in Table 1 and Fig. 2.

The purpose of this task is to apply N fertility treatments in an accurate method. The experimental design is a RCB design with N treatments arranged in a 4×3 factorial. There are four N sources and three N rates. Each fertilizer is applied at the same three rates. Nitrogen treatments will be applied to 5.0- $\times$ 7.0-ft plots by hand to ensure accuracy. A no nitrogen check treatment is also included. Date of fertilizer application was held constant (N source and rate varied) in order to facilitate N uptake calculations and comparisons among N treatments. Ideally, the treatment design and data collection will result in a greater understanding of the influence of N treatments on tall fescue performance and concentration of NO_3^--N and NH_4^+-N in soil water at a depth below the rootzone.

An interim and annual report, including the progress of Task 1, will be submitted to CDFA-FREP on 31 July 2004 and 31 January 2005, respectively.

Month of initiation: 1/04
Month of completion: 12/04

Task 2: Implement data collection according to protocol described in Table 2.

The purpose of this task is to quantify adequately, via sound methodology, the treatment effects on visual appearance, growth (clipping yield), and N uptake of tall fescue, along with NO_3^--N and NH_4^+-N concentration in soil water below the rootzone. Since weather conditions also influence plant and soil measurements, detailed weather data will be collected, and may aid in data interpretation. Ideally, proper measurements will be collected in order to test adequately the significance of treatment effects.

An interim and annual report, including the progress of Task 2, will be submitted to CDFA-FREP on 31 July 2004 and 31 January 2005, respectively.

Month of initiation: 1/04
Month of completion: 12/04

Task 3: Implement research plot management according to protocol described in Table 3.

The primary purpose of this task is to ensure representative tall fescue that is maintained under consistent conditions for the duration of the study. This practice will help discern treatment effects. A second purpose of this task is to ensure accurate and consistent irrigation by frequent irrigation-system monitoring.

An interim and annual report, including the progress of Task 3, will be submitted to CDFA-FREP on 31 July 2004 and 31 January 2005, respectively.

Month of initiation: 1/04
Month of completion: 12/04

Task 4: Implement outreach activities. (Please note there will be one outreach activity in 2004 and two in 2005).

Though there are no outreach activities planned during 2004 at UC Davis, it is possible they will occur by field demonstrations and presentations.

An interim and annual report, including the progress of Task 4, will be submitted to CDFA-FREP on 31 July 2004 and 31 January 2005, respectively.

Month of initiation: 1/04
Month of completion: 12/04

Task 5: Prepare interim and annual reports.

Reports will detail the progress of Tasks 1 to 4. These reports will provide the tool for evaluating the activity for the third 12 months of this project. Interim report will be submitted 31 July 2004 while the annual report will be submitted 31 January 2005.

Month of initiation: 5/04
Month of completion: 1/05

Work Plan: YEAR 4 (January to September 2005)

(Added April 2004)

YEAR 4: January to September 2005 at UC Riverside

Task 1: Implement treatments according to protocol described in Table 1 and Fig. 1.

Not applicable, since the last N fertility treatment application was made on approximately 15 August 2004.

Task 2: Implement data collection according to protocol described in Table 2.

The purpose of this task is to quantify adequately, via sound methodology, the treatment effects on visual appearance, growth (clipping yield), and N uptake of tall fescue, along with NO_3^--N and NH_4^+-N concentration in soil water below the rootzone and in the soil profile. Since weather conditions also influence plant and soil measurements, detailed weather data will be collected, and may aid in data interpretation. Ideally, proper measurements will be collected in order to test adequately the significance of treatment effects. The 24-month period of field data collection ended on approximately 15 October 2004. However, the process of data development will continue (tissue preparation for TKN analysis and data organization, analysis, and summary).

A final report, including the progress of Task 2, will be submitted to CDFA-FREP on 30 Sept. 2005.

Month of initiation: 1/05
Month of completion: 3/05

Task 3: Implement research plot management according to protocol described in Table 3.

Not applicable, since the 24-month period of field data collection ended on approximately 15 October 2004.

Task 4: Implement outreach activities.

The purpose of this task is to present one oral presentation concerning the background and objectives of the research project. Results and conclusions from the research project will be included. The presentation will occur at either general grower meetings, at the UCR Turfgrass Research Conference and Field Day, or at specially planned meetings and/or tours. However, the CDFA FREP Annual Conference would be a good location to give this presentation. The task product will be one oral presentation.

A final report, including the progress of Task 4, will be submitted to CDFA FREP on 30 Sept. 2005.

Month of initiation: 1/05
Month of completion: 9/05

Subtask 4.1: Identify target audience, plan and prepare a presentation, identify potential meetings and dates where the presentation may be delivered. Complete by 4/05.

Subtask 4.2: Present one oral presentation. Complete by 9/05.

Task 5: Prepare final report.

Final report will provide a complete reporting of entire study. This report will provide one tool for evaluating the project as a whole. Final report will be submitted to CDFA-FREP by 30 Sept. 2005.

Month of initiation: 4/05
Month of completion: 9/05

YEAR 4: January to September 2005 at UC Davis

Task 1: Implement treatments according to protocol described in Table 1 and Fig. 2.

The purpose of this task is to apply N fertility treatments in an accurate method. The experimental design is a RCB design with N treatments arranged in a 4×3 factorial. There are four N sources and three N rates. Each fertilizer is applied at the same three rates. Nitrogen treatments will be applied to 5.0- $\times$ 7.0-ft plots by hand to ensure accuracy. A no nitrogen check treatment is also included. Date of fertilizer application was held constant (N source and rate varied) in order to facilitate N uptake calculations and comparisons among N treatments. Ideally, the treatment design and data collection will result in a greater understanding of the influence of N treatments on tall fescue performance and concentration of NO_3^--N and NH_4^+-N in soil water at a depth below the rootzone. The last N fertility treatment application will be made on 1 March 2005.

A final report, including the progress of Task 1, will be submitted to CDFA-FREP on 30 Sept. 2005.

Month of initiation: 1/05
Month of completion: 3/05

Task 2: Implement data collection according to protocol described in Table 2.

The purpose of this task is to quantify adequately, via sound methodology, the treatment effects on visual appearance, growth (clipping yield), and N uptake of tall fescue, along with NO_3^--N and NH_4^+-N concentration in soil water below the rootzone. Since weather conditions also influence plant and soil measurements, detailed weather data will be collected, and may aid in data interpretation. Ideally, proper measurements will be collected in order to test adequately the significance of treatment effects. The 24-month period of field data collection will end on approximately 15 May 2005. However, the process of data development will continue (tissue preparation for TKN analysis and data organization, analysis, and summary).

A final report, including the progress of Task 2, will be submitted to CDFA-FREP on 30 Sept. 2005.

Month of initiation: 1/05
Month of completion: 8/05

Task 3: Implement research plot management according to protocol described in Table 3.

The primary purpose of this task is to ensure representative tall fescue that is maintained under consistent conditions for the duration of the study. This practice will help discern treatment effects. A second purpose of this task is to ensure accurate and consistent irrigation by frequent irrigation-system monitoring. The 24-month period of field data collection will end on approximately 15 May 2005.

A final report, including the progress of Task 3, will be submitted to CDFA-FREP on 30 Sept. 2005.

Month of initiation: 1/05
Month of completion: 5/05

Task 4: Implement outreach activities.

The purpose of this task is to present one oral presentation concerning the background and objectives of the research project. Results and conclusions from the research project will also be included. The presentation will occur at either general grower meetings, at the UCR Turfgrass Research Conference and Field Day, or at specially planned meetings and/or tours. However, the CDFA FREP Annual Conference would be a good location to give this presentation. The task product will be one oral presentation.

A final report, including the progress of Task 4, will be submitted to CDFA FREP on 30 Sept. 2005.

Month of initiation: 1/05
Month of completion: 9/05

> **Subtask 4.1:** Identify target audience, plan and prepare a presentation, identify potential meetings and dates where the presentation may be delivered. Complete by 4/05.
>
> **Subtask 4.2:** Present one oral presentation. Complete by 9/05.

Task 5: Prepare final report.

Final report will provide a complete reporting of entire study. This report will provide one tool for evaluating the project as a whole. Final report will be submitted to CDFA-FREP by 30 Sept. 2005.

Month of initiation: 6/05
Month of completion: 9/05

Table 1. Protocol for 13 N fertilization treatments for the CDFA-FREP study (four N sources x three rates plus a no-nitrogen check).

Date of application	N source[z] (N-P_2O_5-K_2O)	Rate (lb N/1000 ft^2) a	b	c
1 Mar.	No nitrogen check	0.0	0.0	0.0
	A. Ammonium nitrate 34-0-0	1.0	1.5	2.0
	B. Polyon 43-0-0	1.0	1.5	2.0
	C. Milorganite 6-2-0	1.0	1.5	2.0
	D. Nutralene 40-0-0	1.0	1.5	2.0
15 May	No nitrogen check	0.0	0.0	0.0
	A. Ammonium nitrate 34-0-0	1.0	1.5	2.0
	B. Polyon 42-0-0	1.0	1.5	2.0
	C. Milorganite 6-2-0	1.0	1.5	2.0
	D. Nutralene 40-0-0	1.0	1.5	2.0
15 Aug.	No nitrogen check	0.0	0.0	0.0
	A. Ammonium nitrate 34-0-0	1.0	1.5	2.0
	B. Polyon 42-0-0	1.0	1.5	2.0
	C. Milorganite 6-2-0	1.0	1.5	2.0
	D. Nutralene 40-0-0	1.0	1.5	2.0
15 Oct.	No nitrogen check	0.0	0.0	0.0
	A. Ammonium nitrate 34-0-0	1.0	1.5	2.0
	B. Polyon 43-0-0	1.0	1.5	2.0
	C. Milorganite 6-2-0	1.0	1.5	2.0
	D. Nutralene 40-0-0	1.0	1.5	2.0
Total	No nitrogen check	0.0	0.0	0.0
	A. Ammonium nitrate 34-0-0	4.0	6.0	8.0
	B. Polyon 43-0-0 and 42-0-0	4.0	6.0	8.0
	C. Milorganite 6-2-0	4.0	6.0	8.0
	D. Nutralene 40-0-0	4.0	6.0	8.0

[z] Ammonium nitrate is a fast-release, water soluble N source; Polyon is a slow-release, polymer-coated N source; Milorganite is a slow-release, natural organic N source; and Nutralene is a slow-release, water insoluble, methylene ureas N source.

Note: Potassium sulfate (0-0-50) and treble superphosphate (0-45-0) will be applied to all plots at an annual rate of 4.0 lb K_2O/1000 ft^2 and 3.0 lb P_2O_5/1000 ft^2.

Rev. 5 Mar. 2004

Figure 1. Plot plan for development of BMPs for fertilizing lawns to optimize plant performance and nitrogen uptake while reducing the potential for nitrate leaching (UC Riverside).

I | II | N→

70 ft | 7 ft | 5 ft | 30 ft

1 5	2 13	3 12	4	5 10	6 5	7 4	8 7	9	10 12
11 4	12 9	13 2	14 3	15 8	16 10	17 TDR	18 8	19 1	20 3
21 1	22	23 11	24 6	25 7	26 2	27 11	28 9	29 6	30 13
31 2	32 1	33 8	34 TDR	35 12	36 4	37 8	38 TDR	39 10	40 7
41 5	42 4	43 TDR	44 7	45 9	46 12	47 5	48 9	49 11	50 3
51 10	52 6	53 13	54 11	55 3	56 2	57 1	58 13	59 ⌖	60 6

⌖ Soil temperature datalogger

III | IV

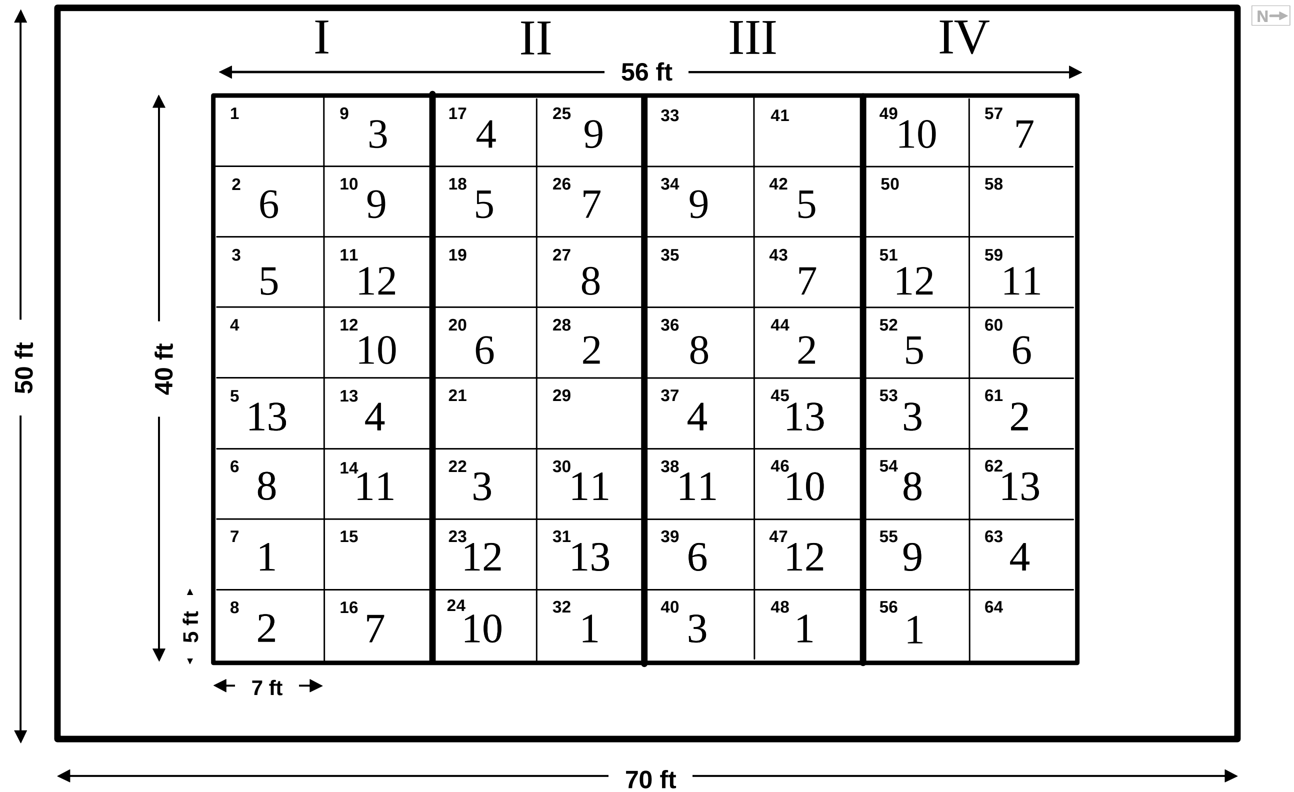
Treatments:

1 – Ammonium nitrate at annual rate of 4 lb N/1000 ft^2
2 – Ammonium nitrate at annual rate of 6 lb N/1000 ft^2
3 – Ammonium nitrate at annual rate of 8 lb N/1000 ft^2
4 – Polyon at annual rate of 4 lb N/1000 ft^2
5 – Polyon at annual rate of 6 lb N/1000 ft^2
6 – Polyon at annual rate of 8 lb N/1000 ft^2
7 – Milorganite at annual rate of 4 lb N/1000 ft^2
8 – Milorganite at annual rate of 6 lb N/1000 ft^2
9 – Milorganite at annual rate of 8 lb N/1000 ft^2
10 – Nutralene at annual rate of 4 lb N/1000 ft^2
11 – Nutralene at annual rate of 6 lb N/1000 ft^2
12 – Nutralene at annual rate of 8 lb N/1000 ft^2
13 – Control (no-nitrogen check)

I, II, III, IV = replications of a randomized complete block design.
Shaded plots are null plots.
Numbers in upper left corner are plot numbers.
TDR = Time domain reflectometry sensors installed in upper 48-inch depth zone.

Rev. 5 Mar. 2004

Figure 2. Plot plan for development of BMPs for fertilizing lawns to optimize plant performance and nitrogen uptake while reducing the potential for nitrate leaching (UC Davis).



Treatments:

1 – Ammonium nitrate at annual rate of 4 lb N/1000 ft^2
2 – Ammonium nitrate at annual rate of 6 lb N/1000 ft^2
3 – Ammonium nitrate at annual rate of 8 lb N/1000 ft^2
4 – Polyon at annual rate of 4 lb N/1000 ft^2
5 – Polyon at annual rate of 6 lb N/1000 ft^2
6 – Polyon at annual rate of 8 lb N/1000 ft^2
7 – Milorganite at annual rate of 4 lb N/1000 ft^2
8 – Milorganite at annual rate of 6 lb N/1000 ft^2
9 – Milorganite at annual rate of 8 lb N/1000 ft^2
10 – Nutralene at annual rate of 4 lb N/1000 ft^2
11 – Nutralene at annual rate of 6 lb N/1000 ft^2
12 – Nutralene at annual rate of 8 lb N/1000 ft^2
13 – Control (no-nitrogen check)

I, II, III, IV = replications of a randomized complete block design.
Plots without a treatment number are null plots.
Numbers in upper left corner are plot numbers.

Rev. 28 Jan. 2005

Table 2. Protocol for measurements collected during the CDFA-FREP study.

Measurement	Frequency	Method and other comments
1. Visual turfgrass quality	Once every 2 weeks	1 to 9 scale, with 1 = worst quality, 5 = minimally acceptable quality, and 9 = best quality for tall fescue
2. Visual turfgrass color	Same time as turfgrass quality	1 to 9 scale, with 1 = worst color (brown), 5 = minimally acceptable color, and 9 = best color (dark green) for tall fescue
3. Clipping yield, TKN, and N uptake	Four growth periods, with each period spanning four consecutive weekly clipping yields. All periods start one month following each of the four N-fertility treatment application dates (Table 1). Generally, periods are: 1 Apr. to 30 Apr.; 15 June to 15 July; 15 Sept. to 15 Oct.; and 15 Nov. to 15 Dec.	Weekly clipping yield, representing 7-d growth, is collected from 9.2 ft^2 (26% of the total surface area) from each plot with the same mower used for routine mowing, except a specially constructed collection box is attached to the mower. Weekly clipping yields are dried at 60 to 67 °C in a forced-air oven for 48 h and immediately weighed. Yield reported as $g \cdot m^{-2}$. The four weekly yields within each growth period are pooled by the 52 plots and ground. TKN analysis is conducted at the DANR laboratory located at UC Davis. With appropriate calculations, N uptake during four 4-week growth periods is determined.
4. NO_3^--N and NH_4^+-N concentration of soil water below rootzone	Once every 2 weeks	One suction plate lysimeter was installed in each plot so the distal tip of the lysimeter cup is at a depth of 2.5 ft below the soil-thatch layer (approximately 0.6 inch deep). The lysimeters were installed at a 45° angle so the lysimeter cup is below undisturbed soil. They were constructed using high-flow ceramic cups (round bottom neck top cups, 1.9-inch diameter, Soil Moisture Equipment Corp. catalog number 653X01-B01M3) and 2-inch diameter PVC pipe. A vacuum of approximately −40 KPa is applied to the lysimeters 24 h before the leachate sampling day. Samples are acidified to pH 2.4-2.8, frozen, and stored until shipped via next-day air to the DANR Laboratory, then stored at 4 °C until analyzed for NO_3^--N and NH_4^+-N by flow injection analyzer method. Analysis occurs within 28 d of leachate collection.
5. Soil water content	Once every 7 d	Volumetric soil water content is determined from the 0- to 48-inch soil depth zone at the same time each Wednesday using four time domain reflectometry (TDR) sensors (MoisturePoint MP-917 TDR unit with Type 2 probe) installed in four null plots within the research plot. The most recent irrigation event is on Tuesday mornings.
6. NO_3^--N and NH_4^+-N concentration in soil	Beginning of study (20 Dec. 2002) and at 12 months (1 Oct. 2003) and 24 months (1 Oct. 2004) after initial fertilizer treatments	Two soil cores are taken from each plot and separated into two soil depth zones for the initial sampling: 0 to 12 inches and 12 to 30 inches. For the second and third sampling, cores are separated into three soil depth zones: 0 to 12 inches, 12 to 24 inches, and 24 to 36 inches. A grid is used to ensure that no part of the plot is sampled more than once for the duration of the study. Cores from each plot are pooled by depth; 6 g soil from each plot and depth zone is immediately placed in 40 ml of 2 M KCl to begin the extraction process. Standard procedures are followed to determine NO_3^--N and NH_4^+-N concentration on a dry soil basis.
7. Weather data	Continuous	Data obtained from a CIMIS station located at the UCR Turfgrass Research Facility. Soil-temperature data loggers also are installed on the research plot.
8. Statistical procedures (to date)		Most measured variables are statistically analyzed according to a RCB design with 12 treatments arranged in a 4×3 factorial. When the no-nitrogen check treatment is included, a RCB design is used to analyze all 13 treatments. Overall analyses involved a repeated measures design, with measurement date as the repeated measures factor.

Rev. 27 Aug. 2004

Table 3. Protocol for research plot management and associated information for the CDFA-FREP study.

Activity	Comment
Mowing	Once each week, using a walk-behind, rotary mower set at a 1.5-inch mowing height. Clippings collected.
Irrigation	**From 16 Oct. 2002 to 1 July 2003: (100% ET_{crop}/DU) minus rainfall (Fig. 20, Table 24a).** • ET_{crop} = ET_o x crop coefficient (K_c). Monthly cool-season K_c (Table 4) used in the calculations. • ET_o = previous 7 d cumulative ET_o, obtained from an on-site CIMIS station • DU = distribution uniformity (Table 25). • Three irrigation events per week. Irrigation events are cycled to prevent runoff. • Total irrigation applied = 73% ET_o; total rainfall = 279.1 mm. • Though visual ratings were not affected, this minimalist irrigation protocol, which attempted to make up rainfall, created some dry soil conditions, especially in the 0- to 6-inch root zone depth (Fig. 21). • To alleviate having to micromanage the plot on the "edge" we changed the irrigation protocol as noted below. **From 2 July 2003 to 12 Oct. 2004: 110% ET_o (Fig. 20, Table 24b).** • 110% ET_o is consistent with our historical knowledge of maintaining tall fescue during the summer in Riverside, Calif. • ET_o = previous 7 d cumulative ET_o, obtained from an on-site CIMIS station • Three irrigation events per week. Irrigation events are cycled to prevent runoff. • Rain is not subtracted from the irrigation amount but may result in a cancellation of an irrigation event if it is $\geq$ 6 mm. • Total irrigation applied = 117% ET_o; total rainfall = 175.4 mm.
Irrigation-system check	To ensure accurate and consistent irrigation, the vertical of all heads is checked with a level and adjusted once every 4 weeks and clock operation and irrigation run times are routinely monitored via a log on the controller. Catch-can tests are conducted prior to the initialization of fertilizer treatments and in Jan. 2003 and Mar. 2004 (Table 25).
Fertility	Potassium sulfate (0-0-50) and treble superphosphate (0-45-0) are applied to all plots at an annual rate of 4.0 lb K_2O/1000 ft^2 and 3.0 lb P_2O_5/1000 ft^2. Application of K_2O, at a rate of 1.0 lb/1000 ft^2, is made in April, May, October, and November. Application of P_2O_5, at a rate of 1.5 lb/1000 ft^2, is made in April and November. An annual soil test is taken in Dec. 2001, 2002, and 2003.
Pesticide application	In order to ensure representative tall fescue, pesticides will be applied as needed. To date, fungicides have been applied to treat *Rhizoctonia* brown patch.

Rev. 28 Jan. 2005

Table 4. Cool- and warm-season turfgrass crop coefficients (K_c) developed in Irvine, Calif. with monthly, quarterly, semi-annual, and annual irrigation programming.

	Cool-season crop coefficients (K_c) [z]				Warm-season crop coefficients (K_c)[z]			
Month	Monthly	Quarterly	Semi-annually	Annually	Monthly	Quarterly	Semi-annually	Annually
April	1.04	0.96	0.90	0.79	0.72	0.73	0.71	0.65
May	0.95				0.79			
June	0.88				0.68			
July	0.94	0.85			0.71	0.68		
August	0.86				0.71			
September	0.74				0.62			
October	0.75	0.68	0.67		0.54	0.56	0.59	
November	0.69				0.58			
December	0.60				0.55			
January	0.61	0.67			0.55	0.62		
February	0.64				0.54			
March	0.75				0.76			

[z] Meyer, J.L., V.A. Gibeault, and V.B. Youngner. 1985. Irrigation of turfgrass below replacement of evapotranspiration as a means of water conservation: Determining crop coefficient of turfgrasses, p. 357-364. In: F. Lemaire (ed.). Proc. 5th Intl. Turfgrass Res. Conf., Avignon, France, July 1985. INRA Publications, Versailles, France.

Table 5.1. Calendar of major activities associated with the field research study at UC Riverside, 12 Dec. 2001 to 16 May 2003.

Date	Activity
12 Dec. 2001	Soil sample collected for analyses of soil salinity/alkalinity/toxicity, fertility, and textural characteristics (for soil sampling schedule see Table 3).
	Samples collected for root mass density (for data see Table 28).
22 Mar.-17 May 2002	Materials collected for constructing lysimeters.
9-12 Apr. 2002	Irrigation catch-can tests.
14 Apr. 2002	Applied 1.0 lb K_2O/1000 ft^2 and 0.75 lb P_2O_5/1000 ft^2.
22 Apr. 2002	Research plots laid out; finalization of plot plan.
17 May-8 July 2002	Construction of lysimeters.
10 June-15 July 2002	Lysimeters installed [at 76.2-cm (2.5-ft) depth].
12-20 June 2002	Irrigation catch-can tests.
11-17 July 2002	Lysimeters tested for ability to hold vacuum and collect leachate.
18 July-14 Oct. 2002	Time allowed for disturbed soil surrounding lysimeters to equilibrate after field installation.
5-27 Sept. 2002	Time domain reflectometry (TDR) probes installed and tested.
3 Oct. 2002	Datalogger installed; beginning of hourly soil temperature readings [at 10.2-cm (4-inch) depth] for duration of study (for details see Table 2).
9 Oct. 2002	Baseline leachate collection (analyzed for NO_3^--N only).
10 Oct. 2002	Baseline TDR measurements.
14 Oct. 2002	Mowing regime set for duration of study to once per week at a 3.8-cm (1.5-inch) mowing height with a walk-behind Toro rotary mower (clippings collected) (for details see Table 3).
16 Oct. 2002	Irrigation protocol established at (100% ET_{crop}/DU) minus rainfall (for details see Table 3).
	Initial TDR measurement for Year 1; subsequently taken once every week (for details see Table 2).
17 Oct. 2002	Initial irrigation under protocol; subsequently irrigated three times per week on Tuesday, Thursday and Saturday mornings for the duration of the study.
18 Oct. 2002	Applied 1.0 lb K_2O/1000 ft^2 (for details see Table 3).
	First application of N-fertility treatments for Year 1 (for details see Table 1).
	Initial irrigation system check; subsequently performed monthly for duration of study (for details see Table 3).
30 Oct. 2002	Initial leachate collection for Year 1; subsequently taken every 2 weeks (for details see Table 2). Note: analyzed for NO_3^--N only through 8 Jan. 2003.
6 Nov. 2002	Initial visual turfgrass quality and color ratings for Year 1; subsequently taken every 2 weeks (for details see Table 2).
15 Nov. 2002	Applied 1.0 lb K_2O/1000 ft^2 and 1.5 lb P_2O_5/1000 ft^2.
15 Nov.-6 Dec. 2002	First 4-week clipping yield collection period (taken once per week from 7 d of growth) for Year 1 (for details see Table 2).
16 Dec. 2002	Soil sample collected for analysis of soil salinity/alkalinity/toxicity, fertility, and textual characteristics.
18 Dec. 2002	Soil cores taken for analysis of NO_3^--N and NH_4^+-N in soil (for details see Table 2).
22 Jan. 2003	First leachate collection for which analyses for both NO_3^--N and NH_4^+-N were conducted.
3 Mar. 2003	Second application of N-fertility treatments for Year 1.
28 Mar.-18 Apr. 2003	Second 4-week clipping yield collection period (taken once per week from 7 d of growth) for Year 1.
18 Apr. 2003	Applied 1.0 lb K_2O/1000 ft^2 and 1.5 lb P_2O_5/1000 ft^2.
15-16 May 2003	Third application of N-fertility treatments for Year 1.
16 May 2003	Applied 1.0 lb K_2O/1000 ft^2.

Table 5.2. Calendar of major activities associated with the field research study at UC Riverside, 13 June 2003 to 13 Oct. 2004.

Date	Activity
13 June-4 July 2003	Third 4-week clipping yield collection period (taken once per week from 7 d of growth) for Year 1.
2 July 2003	Irrigation protocol established at 110% ET_o (for details see Table 3).
3 July 2003	Initial irrigation under new protocol; all subsequent irrigation events for study under this protocol.
22 July 2003	Fungicide application to control *Rhizoctonia* brown patch (Heritage, 0.4 oz/1000 ft^2).
8 Aug. 2003	Fungicide application to control *Rhizoctonia* brown patch (Daconil Ultrex, 5.5 oz/1000 ft^2).
15 Aug. 2003	Fourth application of N-fertility treatments for Year 1.
12 Sept.-3 Oct. 2003	Fourth 4-week clipping yield collection period (taken once per week from 7 d of growth) for Year 1.
1 Oct. 2003	Final leachate collection for Year 1.
8 Oct. 2003	Final TDR measurement for Year 1.
9 Oct. 2003	Soil cores taken for analysis of NO_3^--N and NH_4^+-N in soil.
10 Oct. 2003	Final visual turfgrass quality and color ratings for Year 1.
24 Oct. 2003	Initial visual turfgrass quality and color ratings for Year 2; subsequently taken every 2 weeks.
15 Oct. 2003	Initial TDR measurement for Year 2; subsequently taken once every week.
	Initial leachate collection for Year 2; subsequently taken every 2 weeks.
17 Oct. 2003	Applied 1.0 lb K_2O/1000 ft^2.
	First application of N-fertility treatments for Year 2.
14 Nov.-5 Dec. 2003	First 4-week clipping yield collection period (taken once per week from 7 d of growth) for Year 2.
19 Nov. 2003	Applied 1.0 lb K_2O/1000 ft^2 and 1.5 lb P_2O_5/1000 ft^2.
24 Dec. 2003	Soil sample collected for analysis of soil salinity/alkalinity/toxicity, fertility, and textural characteristics.
2-3 Mar. 2004	Second application of N-fertility treatments for Year 2.
26 Mar.-16 Apr. 2004	Second 4-week clipping yield collection period (taken once per week from 7 d of growth) for Year 2.
21 Apr. 2004	Applied 1.0 lb K_2O/1000 ft^2 and 1.5 lb P_2O_5/1000 ft^2.
13 May 2004	Third application of N-fertility treatments for Year 2.
14 May 2004	Applied 1.0 lb K_2O/1000 ft^2.
11 June-2 July 2004	Third 4-week clipping yield collection period (taken once per week from 7 d of growth) for Year 2.
10 Aug. 2004	Fungicide application to control *Rhizoctonia* brown patch (Daconil Ultrex, 6 oz/1000 ft^2).
13 Aug. 2004	Fourth application of N-fertility treatments for Year 2.
27 Aug. 2004	Fungicide application to control *Rhizoctonia* brown patch (Daconil Ultrex, 7 oz/1000 ft^2).
6 Sept. 2004	Fungicide application to control *Rhizoctonia* brown patch (Heritage, 0.45 oz/1000 ft^2).
10 Sept.-1 Oct. 2004	Fourth 4-week clipping yield collection period (taken once per week from 7 d of growth) for Year 2.
29 Sept. 2004	Final leachate collection for Year 2.
6 Oct. 2004	Soil cores taken for analysis of NO_3^--N and NH_4^+-N in soil.
	Final TDR measurement for Year 2.
8 Oct. 2004	Final visual turfgrass quality and color ratings for Year 2.
13 Oct. 2004	Soil temperature data collection terminated.

CHAPTER 3: RESULTS, DISCUSSION AND CONCLUSIONS

Results, Discussion, and Conclusions

UC Riverside

Visual turfgrass quality ratings

Visual turfgrass quality ratings measure appearance based on several characteristics that normally include color, texture (leaf width and length), uniformity, and density. It should be noted that each characteristic also can be rated by visual means.

This report covers data and analyses of visual turfgrass quality for 48 rating dates, taken from 6 Nov. 2002 to 8 Oct. 2004 (Fig. 6 to 8; Tables 12.1 to 12.4, 14 and 15).

In terms of overall analyses of 13 treatments (Table 14), all fertilizer treatments were within range of an acceptable tall fescue lawn. This assumes that most people are satisfied with a tall fescue lawn when visual turfgrass quality is within the range of 5.5 to 6.5 (1 to 9 scale, with 1 = worst, 5 = minimally acceptable, and 9 = best tall fescue). Overall visual turfgrass quality ranged from 5.5 for Milorganite at an annual N rate of 4.0 lb/1000 ft^2 to 6.2 for ammonium nitrate and Polyon at an annual N rate of 8.0 lb/1000 ft^2; the check treatment was 4.8.

In terms of overall analyses of 12 fertilizer treatments, arranged in a 4×3 factorial design (Table 14), ammonium nitrate and Polyon produced overall visual turfgrass quality of 6.0 while Milorganite and Nutralene produced 5.8 and 5.9, respectively. Also, annual N rates of 8, 6, and 4 lb/1000 ft^2 produced overall visual turfgrass quality of 6.1, 5.9, and 5.7, respectively.

The number of rating dates on which visual turfgrass quality achieved a set threshold value is shown in Table 15. This information is an indicator of consistency. In terms of 48 rating dates, all fertilizer treatments resulted in a visual turfgrass quality rating $\geq$ 5.5 on 24 or more rating dates. Fertilizer treatments that resulted in a visual turfgrass quality rating $\geq$ 6.0 on 24 or more rating dates included all fertilizer sources at the annual N rate of 8.0 lb/1000 ft^2; all fertilizer sources at the annual N rate of 6.0 lb/1000 ft^2, except for Nutralene; and only one fertilizer source (ammonium nitrate) at the annual rate of 4.0 lb/1000 ft^2.

Also, the number of rating dates that visual turfgrass quality was $\geq$ 5.5 increased for all fertilizer treatments when the first 12 months of the field study are compared to the second 12 months (exception is Polyon at the annual N rate of 6.0 and 8.0 lb/1000 ft^2; during both periods both treatments were $\geq$ 5.5 on all rating dates; 24 rating dates for each period). This increase was greater for slow-release N carriers, such as Nutralene and Milorganite, which require bacterial transformation of organically bound N to simple organic forms (Tables 7 and 8).

Visual turfgrass color ratings

Visual turfgrass color is an important component of visual turfgrass quality. This report covers data and analyses of visual turfgrass color for 50 rating dates, taken from 6 Nov. 2002 to 8 Oct. 2004 (Fig. 9 to 11; Tables 13.1 to 13.5, 14 and 16).

In terms of overall analyses of 13 treatments (Table 14), all fertilizer treatments were within range of an acceptable tall fescue lawn. This assumes that most people are satisfied with a tall fescue lawn when visual turfgrass color is within the range of 5.5 to 6.5 (1 to 9 scale, with 1 = brown, 5 = minimally acceptable, and 9 = darkest green tall fescue). Overall visual turfgrass color ranged from 5.8 for Milorganite at an annual N rate of 4.0 lb/1000 ft^2 to 6.6 for Polyon at an annual N rate of 8.0 lb/1000 ft^2; the check treatment was 5.0.

In terms of overall analyses of 12 fertilizer treatments, arranged in a 4×3 factorial design (Table 14), ammonium nitrate, Polyon, Nutralene, and Milorganite produced overall visual turfgrass color of 6.3, 6.3, 6.1, and 6.1, respectively. Also, annual N rates of 8, 6, and 4 lb/1000 ft^2 produced overall visual turfgrass color of 6.4, 6.2, and 6.0, respectively.

In terms of 50 rating dates, all fertilizer treatments resulted in a visual turfgrass color rating $\geq$ 5.5 on 25% or more rating dates. Also, all fertilizer treatments resulted in a visual turfgrass color rating $\geq$ 6.0 on 25% or more rating dates except Milorganite at an annual N rate of 4.0 lb/1000 ft^2.

Incidence of **Rhizoctonia** *brown patch*

During the summer of 2004, there was an outbreak of *Rhizoctonia* brown patch activity, so ratings were taken on percent coverage (Table 17). Also, three fungicide applications were made on 10 Aug., 27 Aug., and 6 Sept. 2004 (Table 5.2) to control this disease activity. Though there were not any significant differences between treatments for percent coverage of *Rhizoctonia* brown patch, there was a trend for higher N fertilizer rates to have more disease coverage.

Concentration of NO_3^--N in leachate

Data for NO_3^--N concentrations in leachate on 48 sample dates from 9 Oct. 2002 to 29 Sept. 2004 are shown in Fig. 12 to 14 and Tables 18.1 to 18.4.

These data were affected by a change in irrigation protocol on 2 July 2003 (Table 3, Fig. 20). From 16 Oct. 2002 to 1 July 2003, the protocol was (100% ET_{crop}/DU) minus rainfall, based on the previous 7 d cumulative ET_o (Table 24a). The goal of this protocol was to irrigate according to plant water use needs and not to over-irrigate nor under-irrigate. However, we gradually realized that in making up rainfall, we may have caused some dry soil conditions, especially in the 0- to 6-inch soil depth zone (Fig. 21). However, visual drought symptoms were not apparent on all dates, when visual turfgrass quality and color ratings were taken. To alleviate this situation of trying to micromanage a plot that was maintained on the “edge” in terms of plant water use and soil water depletion, we decided to fall back on our historical knowledge of maintaining tall fescue during the summer in Riverside; that is 110% ET_o, based on the previous 7 day cumulative ET_o. Thus, we initiated the new irrigation protocol on 2 July 2003 and continued it until the end of the field study which was 12 Oct. 2004 (Table 24b).

During minimalist irrigation from 16 Oct. 2002 to 1 July 2003, NO_3^--N concentrations in leachate were low (< 1 ppm) and differences among fertilizer treatments were basically not significant (Fig. 12 to 14 and Tables 18.1 and 18.2). It should be noted that the average NO_3^--N concentration of irrigation water was 4.31 ppm (Table 20).

During well-watered irrigation from 2 July 2003 to 29 Sept. 2004, NO_3^--N concentration in leachate was higher than the previous period (Figs. 12 to 14). However, concentrations are probably not problematic except for one fertilizer treatment: ammonium nitrate at an annual N rate of 8.0 lb/1000 ft^2 (four applications at an N rate of 2.0 lb/1000 ft^2). On several sample dates during the months of September through December, NO_3^--N concentration in leachate exceeded 10 ppm. Data also showed significant N source (Fig. 13) and N rate (Fig. 14) effects on concentration of NO_3^--N in leachate. Basically, ammonium nitrate and the annual N rate of 8.0 lb/1000 ft^2 resulted in the highest concentrations of NO_3^--N in leachate.

These data concerning nitrate leaching, from a well-established tall fescue, will help support BMPs for fertilizing tall fescue lawns to optimize plant performance and nitrogen uptake while reducing the potential for nitrate leaching. Listed below are several BMPs.

1. Minimalist irrigation reduces the potential for nitrate leaching. However, sufficient irrigation is needed to promote healthy turfgrass.

2. An annual N rate of 4 to 6 lb/1000 ft^2 produces an acceptable to good quality tall fescue lawn (Table 6). Higher rates are not necessary and increase the risk of nitrate leaching.

3. Slow-release N sources (Nutralene, Milorganite, and Polyon) cause less nitrate leaching than a fast-release N source (ammonium nitrate).

4. The amount of nitrate leaching from a fast-release N source can be drastically reduced if N rates of individual applications do not exceed 1.0 to 1.5 lb/1000 ft^2.

Concentration of NH_4^+-N in leachate

Data for NH_4^+-N concentration in leachate on 41 sample dates from 22 Jan. 2003 to 29 Sept. 2004 are shown in Fig. 15 to 17 and Tables 19.1 to 19.4. These data show that concentrations were low ($<$ 1 ppm) and the effects of N source (Fig. 16) and N rate (Fig. 17) were not significant except one on one sample date (29 Oct. 2003). It should be noted that the NH_4^+-N concentration in irrigation water was consistently $<$ 0.05 ppm (Table 20) (15 Sept. 2004 was one exception with NH_4^+-N concentration in irrigation water = 0.23 ppm).

Concentration of NO_3^--N and NH_4^+-N in soil

Data for concentrations of NO_3^--N and NH_4^+-N in soil are shown in Fig. 18 and 19 (sample date = 20 Dec. 2002), Tables 21.1a and 21.1b (sample date = 9 Oct. 2003), and Tables 21.2a and 21.2b (sample date = 6 Oct. 2004). During the beginning of the study (20 Dec. 2002), NO_3^--N concentrations were low ($<$ 1 ppm), fairly uniform across the plots, and slightly higher in the 12- to 30-inch soil depth zone than the 0- to 12-inch soil depth zone (Fig. 18). Also, NH_4^+-N concentrations were low ($<$ 1 ppm) and slightly higher in the 0- to 12-inch soil depth zone than the 12- to 30-inch soil depth zone (Fig. 19).

During 1 year following fertilizer treatment applications (9 Oct. 2003), NO_3^--N concentrations were low (< 2 ppm) (Table 21.1a) and significantly affected by the 13 fertilizer treatments but not the three soil depth zones (Table 21.1b). Also, NH_4^+-N concentrations were low (normally < 2 ppm) (Table 21.1a) and not significantly affected by the 13 fertilizer treatments but significantly affected by the three soil depth zones (Table 21.1b); NH_4^+-N soil concentrations were highest at the 0- to 12-inch soil depth zone.

During 2 years following fertilizer treatment applications (6 Oct. 2004), NO_3^--N concentrations were low (< 2 ppm) (Table 21.2a) and significantly affected by the 13 fertilizer treatments and the three soil depth zones (Table 21.2b). Also, NH_4^+-N concentrations were low (< 2 ppm) (Table 21.2a) and not significantly affected by the 13 fertilizer treatments but significantly affected by the three soil depth zones (Table 21.2b); NH_4^+-N soil concentrations were highest at the 0- to 12-inch soil depth zone.

Clipping yield, tissue TKN concentration, and N uptake

Data for clipping yields for all eight 4-week growth periods during the 2-year field study are shown in Tables 22.1 to 22.8. In terms of the 4-week total yield the following observations can be made.

1. The first three 4-week growth periods (Nov. to Dec. 2002; Mar. to Apr. 2003; and June to July 2003) were dramatically reduced by the initial minimalist irrigation protocol of 100% ET_{crop}/DU minus rainfall which was practiced from 16 Oct. 2002 to 1 July 2003 (Table 3; Fig. 20).

2. As might be expected, season of growth periods affected clipping yield: Sept. to Oct. ≈ Mar. to Apr.> June to July > Nov. to Dec. (second year of data only considered). This information is consistent with the clipping yield information developed from 1994 to 2001 (Fig. 3)

3. Ammonium nitrate produced the greatest amount of yield while Milorganite produced the lowest amount of yield.

4. The amount of yield was positively (+) associated to the annual N fertilizer rate.

Data for TKN and N uptake for all eight 4-week growth periods are shown in Tables 23.1 and 23.2. Fertilizer source and rate means (ANOVA, 4 x 3 factorial design, 12 treatments) indicate that there is a positive (+) relationship between N uptake, TKN, and clipping yield.

UC Davis

Work at the UC Davis site commenced in Sept. 2002. A 75- x 50-ft site, comprised of a Yolo Sandy Loam, was immediately adjacent to the greenhouse range for the Department of Environmental Horticulture (now Department of Plant Sciences) and closely simulated the conditions of a homeowner's back yard. Construction of the site involved soil preparation and laser leveling along with the installation of a sprinkler irrigation system similar to the one used at the UC Riverside site. The distribution uniformity (DU) of the irrigation system was tested three times and was never below 88%. Marathon III tall fescue sod was placed on the site in early Oct. 2002.

Fertilizer treatments were initiated in May 2003.

Visual turfgrass quality and color ratings (Tables 30 and 31)

2003

Quality and color rating data was delayed in 2003 until late in the season. However, it was concluded that at this time of year ammonium nitrate, Milorganite, and Nutralene had significantly higher visual turfgrass quality than Polyon. The rate of application was not a significant factor. The untreated check did not have minimally acceptable visual turfgrass quality at this time of year.

Visual turfgrass color followed similar trends. All nitrogen sources produced turfgrass that had minimally acceptable visual turfgrass color when applied at an annual N rate of 8 lb/1000 ft^2, although the visual turfgrass color of the plots treated with Polyon was significantly lower and the color value was judged to be unacceptable; fertilizer application rate was not a significant factor. The untreated check had the lowest mean for visual turfgrass color and was significantly lower than all 12 treatments.

2004

In terms of overall analyses of the 13 treatments, all fertilizers were within range of acceptable tall fescue lawns during the spring and summer months (April to July). In January, all Polyon treatments fell below the minimally acceptable threshold (5.0) as did the lowest rates of Milorganite and Nutralene. This was very nearly the case in December when the treatments with the lowest rate of Polyon, Milorganite and Nutralene were right at or below the threshold. All 13 treatments led to acceptable turfgrass quality and color ratings during the spring and summer months (April, May, June, and July).

Ammonium nitrate and Milorganite applications led to turfgrass quality ratings that stayed at or above the threshold during the entire year; Polyon treatments fell below the threshold during the cooler months of January and December, and Nutralene treatments fell below the threshold in January. During January no fertilizer rate reached the threshold quality deemed minimally acceptable whereas during April, May, June and July all rates did. In December, the N rate of 4.0 lb/1000 ft^2 fell below the threshold. As expected, higher rates of nitrogen led to higher quality turfgrass throughout the year.

2005

Record-breaking rains in Mar. 2005 and the return of *Rhizoctonia* brown patch prevented a consistent and routine collection of visual ratings of the turfgrass for quality and color assessment. Instead, we focused on the collection and analysis of leachate and collection of clipping yield data.

Summary

Most fertilizers and rates resulted in turfgrass that had minimally acceptable quality and color. In particular, ammonium nitrate and Milorganite applications that led to quality and color ratings that stayed above the threshold the whole year. Turfgrass treated with Polyon did not reach minimally acceptable levels during the winter months.

Concentration of NO_3^--N in leachate (Fig. 22 to 24 and Tables 33.1 and 33.2)

2003

Technical difficulties and environmental conditions prevented the collection of enough leachate samples in 2003 and part of 2004 from which to draw conclusions.

2004

NO_3^--N values in January were relatively high due to heavy rains and poor drainage of the entire turfgrass plot. Once into the "normal" growing season (May and after), NO_3^--N values were all quite low and there were no significant differences among any of the 13 treatments. At no time after 5 Jan. 2004 did any of the treatments lead to NO_3^--N values above 10 ppm. Additionally, when the data were analyzed as a 4×3 factorial experiment there were no significant differences among any of the four nitrogen sources or among any of the three rates.

Summary

NO_3^--N concentrations began to increase before fertilizer was applied during the summer months. Mineralization and/or nitrification of soil N could explain these results. Soil temperature rises through the summer, even deep in the profile, can increase microbial processes that would result in increased soil N levels. At the same time, tall fescue roots tend to turn over faster – more senescence, less replacement. It's thus possible that the tall fescue turf had a less effective root system (not even considering disease effects) and increased nitrate production during periods of heat stress. The highest rates of nitrification would likely be in the top 5 cm of soil, but there could be some going on throughout much of the soil profile. Thus, NO_3^--N concentrations will increase even without the addition of N to the soil surface via fertilization.

Clipping yield (Tables 32.1 to 32.7)

2003

Even though clipping yields were only performed twice in 2003 (data not shown), an ANOVA of the 13 treatments showed that ammonium nitrate at an annual N rate of 8 lb/1000 ft^2 consistently had the highest yield and Polyon at an annual N rate of 6 lb/1000 ft^2 had the lowest. Polyon-treated turfgrass had the lowest clipping yield. The rate of fertilizer application was not a significant factor.

2004

During early winter (6 Jan.) there were no significant differences among any of the treatments and the factorial analysis showed no significant differences among any of the nitrogen sources or their rates. However, later in January (22 Jan.), there were significant differences among the treatments with ammonium nitrate causing the highest yield and Polyon causing the lowest. As expected, higher rates of fertilizer resulted in higher yields.

In the spring (late-April to early-May), there were highly significant differences among treatments, where high rates of fertilizer were applied versus low-rate treatments. When the data were analyzed as a 4×3 factorial experiment, the nitrogen source led to highly significant differences during the first 2 weeks of the 4-week period. During the first 2 weeks (21 Apr. and 28 Apr.), ammonium nitrate led to higher clipping yields than any other source of nitrogen. After that there were no significant differences in clipping yield among any of the four fertilizers. The clipping yield was greater when N rates of 8.0 and 6.0 lb/1000 ft^2 were applied for the first 3 weeks of the 4-week period. After that, the fertilizer rate did not make a difference in clipping yield. Total yields for the 4-week period showed that ammonium nitrate fertilization led to higher yields than any of the other three nitrogen sources. Also, the N rate of 8.0 lb/1000 ft^2 led to higher yields than the N rate of 6.0 lb/1000 ft^2 which were also higher than the N rate of 4.0 lb/1000 ft^2.

In the summer (7 July, 14 July, 20 July, and 27 July) there was no consistent pattern to which treatments resulted in the highest clipping yield. However, when looking at the total yield data for the 4-week period the N rates of 6.0 and 8.0 lb/1000 ft^2 for Polyon resulted in the highest total yields. The unfertilized check treatment consistently had the lowest yield during each sample period and when summed over 4 weeks.

When the data were analyzed as a 4×3 factorial experiment, there was no consistent pattern indicating which nitrogen source led to the highest clipping yields. However, during the first three sampling periods, the N rate of 8.0/1000 ft^2 rate led to the highest yields, the N rate of 4.0 lb/1000 ft^2 the lowest, and the N rate of 6.0 lb/1000 ft^2 rate was in between.

<u>**2005**</u>

Clipping yields for four, 4-week time periods (April, May-June, September-October and November-December) are provided in Tables 32.4, 32.5, 32.6 and 32.7. Each tabulated value is the dry mass (in grams) collected on a square meter of turfgrass 7 d after mowing. The turfgrass was still recovering from *Rhizoctonia* brown patch on 13 Sept. so clipping yield data was not collected.

In the spring (5 Apr. to 26 Apr.), there were highly significant differences among treatments, where high rates of fertilizer were applied versus low-rate treatments and all fertilizer treatments led to higher clipping yields than the unfertilized control (see 4-week total yield data in Table 32.4). When the data were analyzed as a 4×3 factorial experiment, there were no significant differences among any of the four nitrogen sources; however, the mean for the Polyon treatments was more than 10% greater than any of the other three N sources. Significant differences among the three N rates (4, 6, and 8 lb/1000ft^2) were found. The rate of N fertilizer, not the source, was the reason for treatment differences found in the ANOVA of the 13 treatments.

Data from the 1 June to 22 June set of data showed identical results except during that time period the Polyon N source showed a significantly higher clipping yield than any of the other three N sources (Table 32.5). This suggests that the earlier, non-significant result with Polyon was the beginning of a trend.

In the early fall (13 Sept. to 4 Oct.) there was no consistent pattern to which source of N or rate resulted in the highest clipping yield (Table 32.6). This is probably due to the fact that the turfgrass was still in recovery from the *Rhizoctonia* brown patch infestation, suffered during late-July and August.

In late-fall (15 Nov. to 6 Dec.) there were no significant differences among any of the four N sources or any of the three fertilizer rates. However, there was trend for higher clipping yields with higher rates, but it was not significant at $P=0.05$.

Summary

Ammonium nitrate applications resulted in the highest clipping yields and Polyon resulted in the lowest yields during the early part of the season. After that (April and later) Polyon treatments resulted in the highest clipping yield. This result along with the results from winter harvests suggests that Polyon is most affected by temperature. In general, higher fertilizer rates resulted in higher clipping yields.

Incidence of* Rhizoctonia *brown patch (Table 34)

2004

In June 2003 and 2004, the plot suffered an infestation of *Rhizoctonia* brown patch. The severity of the damage seemed to be associated with the fertilizer treatments. An estimate of the number of square feet in each plot that was damaged was made on 15 July 2004. Results showed that Milorganite applied at an annual N rate of 8 lb/1000 ft^2 per year was by far the most damaged. When the data were analyzed as a 4×3 factorial experiment, the nitrogen source was a significant factor and showed that damage was worst when Miloganite was used. Additionally, damage was also most severe at the N rate of 8 lb/1000 ft^2. Neither the source of nitrogen nor the rate were significant factors in August.

2005

The entire turf plot area was heavily infested with *Rhizoctonia* brown patch again in late June 2005. Prophylactic applications of fungicide (azoxystrobin, Heritage 50WG 0.1 oz/ 1000ft^2) were made every other week from 15 June until 15 July. Unfortunately, the fungicidal treatments were ineffective in preventing the disease.

Summary

Rhizoctonia brown patch was a serious challenge to the consistent and routine collection of turfgrass quality/color, clipping yield and leachate data.

CHAPTER 4: PROJECT EVALUATION AND OUTREACH ACTIVITIES

Project Evaluation

The objectives of this project are listed below.

1. Evaluate the annual N rate and source on tall fescue to determine which treatments optimize plant performance and N uptake while reducing the potential for NO_3^--N leaching.

2. Quantify the effect of N fertilizer rate and source on: visual turfgrass quality and color; clipping yield, tissue N concentration, and N uptake; and concentration of NO_3^--N in leachate at a depth below the rootzone.

3. Develop BMPs for the fertilization under representative irrigation practices of lawns to optimize plant performance and N uptake while reducing the potential for NO_3^--N leaching.

4. Conduct outreach activities, including oral presentations and trade journal publications, emphasizing the importance of the BMPs and how to carry out these practices for N fertilization of lawns.

We believe all objectives of the project were satisfied. Based on data collected during this study, several BMPs were developed and are listed below.

1. Minimalist irrigation reduces the potential for nitrate leaching. However, sufficient irrigation is needed to promote healthy turfgrass.

2. An annual N rate of 4 to 6 lb/1000 ft^2 produces an acceptable to good quality tall fescue lawn. Higher rates are not necessary and increase the risk of nitrate leaching.

3. Slow-release N sources (Nutralene, Milorganite, and Polyon) cause less nitrate leaching than a fast-release N source (ammonium nitrate).

4. The amount of nitrate leaching from a fast-release N source can be drastically reduced if N rates of individual applications do not exceed 1.0 to 1.5 lb/1000 ft^2.

During this project, there were 20 outreach activities, so we believe the information related to the topic was well conveyed. During the second half of the project, the topic of BMPs was emphasized. Adoption of BMPs can occur over time if the information continues to be conveyed to the general public.

Outreach Activities

There were 20 outreach activities conducted from 2002 to 2006, including 11 oral presentations (one in 2002, three in 2003, two in 2004, two in 2005, and three in 2006) and nine popular journal articles (three in 2002, one in 2003, two in 2004, one in 2005, and two in 2006).

Oral presentation (see Appendix)

1. 9/24/02 "Development of Nitrogen BMPs for Fertilizing Lawns," 2002 Turfgrass and Landscape Management Field Day, University of California, Riverside; approximately 200 participants, including professional turfgrass and landscape managers, personnel involved in the fertilizer and other turfgrass-related industries, educators, and consultants.

2. 11/20/03 "Development of BMPs for Fertilizing Lawns to Optimize Plant Performance and Nitrogen Uptake While Reducing the Potential for Nitrate Leaching," 11th Annual Fertilizer Research and Education Program Conference, Tulare, CA; approximately 125 participants, including growers, PCAs and fertilizer dealers.

3. 12/10/03 "Nitrogen Management in Landscapes to Minimize Leaching," 45th Annual Turfgrass and Landscape Institute, Ontario, CA; approximately 55 participants, primarily professional landscape practitioners.

4. 12/10/03 "Nitrogen Leaching on Golf Courses," 45th Annual Turfgrass and Landscape Institute, Ontario, CA; approximately 40 participants, primarily golf course superintendents.

5. 6/08/04 "Nitrogen Fertilization and Leaching Study on Tall Fescue," University of California Riverside Turfgrass Research Advisory Committee (UCRTRAC) Turfgrass Tour, Riverside, CA; approximately 18 participants, primarily leaders of the southern California turfgrass industry.

6. 11/04/04 "Best Management Practices for Tall Fescue," 2004 Pesticide Applicators Professional Association (PAPA) Meeting, Chico, CA; approximately 250 participants, primarily pesticide applicators and landscape maintenance professionals.

7. 6/07/05 "Diagnostics: ID of Biotic and Abiotic Plant Diseases," 2005 Pesticide Applicators Professional Association (PAPA) Meeting, Montebello, CA; approximately 140 participants, primarily pesticide applicators and landscape maintenance professionals.

8. 11/30/05 "Development of BMPs for Fertilizing Lawns to Optimize Plant Performance and Nitrogen Uptake While Reducing the Potential for Nitrate Leaching," 13th Annual Fertilizer Research and Education Program Conference, Salinas, CA; approximately 125 participants, including growers, PCAs and fertilizer dealers.

9. 02/01/06 "Best Management Practices for Tall Fescue Nitrogen Fertilization to Reduce Groundwater Pollution," 42nd Annual Turf and Landscape Expo, Santa Clara, CA; approximately 200 participants, including landscape and turfgrass management professionals.

10. 05/10/06 "Understanding Soil Types and How They Absorb Water as Part of an IPM Program," 2006 Pesticide Applicators Professional Association (PAPA) Meeting, Rancho Cucamonga, CA; approximately 100 participants, primarily pesticide applicators and landscape maintenance professionals.

11. 03/10/06 "Development of BMPs for Fertilizing Lawns to Optimize Plant Performance and Nitrogen Uptake While Reducing the Potential for Nitrate Leaching," 17th Annual Turf Management Seminar: Implementing Turf Research Results, San Diego, CA; approximately 200 participants, including turfgrass and landscape practitioners.

Popular journal articles (see Appendix)

1. Klein, G.J., R.L. Green, L. Wu, D.W. Burger, J.S. Hartin, and M. Meyer. 2002. Development of nitrogen BMPs for fertilizing lawns. Proc. 2002 Turfgrass and Landscape Management Field Day, University of California, Riverside, Sept. 24, 2002. p. 10-13.

2. Green, R.L., L. Wu, D.W. Burger, G.J. Klein, J.S. Hartin, and M. Meyer. 2002. Development of BMPs for fertilizing lawns to optimize plant performance and nitrogen uptake while reducing the potential for nitrate leaching. Proc. 10th Annu. Fert. Res. Educ. Program Conf. 1:80–83.

3. Meyer, M., D.W. Burger, and R.L. Green. 2002. Review of pesticide and fertilizer use in turfgrass.

4. Green, R.L., L. Wu, D.W. Burger, G.J. Klein, J.S. Hartin, and M. Meyer. 2003. Development of BMPs for fertilizing lawns to optimize plant performance and nitrogen uptake while reducing the potential for nitrate leaching. Proc. 11th Annu. Fert. Res. Educ. Program Conf. 1:85–90.

5. Birkle, D. and L. Wu. 2004. Developing a nitrate leaching hazard index for crop production. WaterWise 1(3):3.

6. Green, R.L. 2004. Research focus: Nitrogen leaching from a well-established tall fescue turf. News from the UCR Turfgrass Program, Nov. 2004. Publication sent to members of the UC Riverside Turfgrass Advisory Committee and to green industry publications. Published at the UCR Turf website at <http://ucrturf.ucr.edu/publications/News/05_Nov%2004/05_Nov04.htm> and also published in *DivotNews* 10(11):8 and *INFOREMER* 13(7&8):4,11.

7. Green, R.L., L. Wu, D.W. Burger, G.J. Klein, J.S. Hartin, and M. Meyer. 2005. Development of BMPs for fertilizing lawns to optimize plant performance and nitrogen uptake while reducing the potential for nitrate leaching. Proc. 13th Annu. Fert. Res. Educ. Program Conf. 1:8–13.

8. Green, R.L., L. Wu, D.W. Burger, G.J. Klein, J.S. Hartin, and M. Meyer. 2006. Development of BMPs for fertilizing lawns to optimize plant performance and nitrogen uptake while reducing the potential for nitrate leaching. Proc. 17th Annu. Turf Mgt. Sem. 1:62–73.

9. Green, R., L. Wu, D. Burger, G. Klein, and J. Hartin. 2006. Development of BMPs for fertilizing tall fescue. Co-Hort 8.1-8.2:1–9.

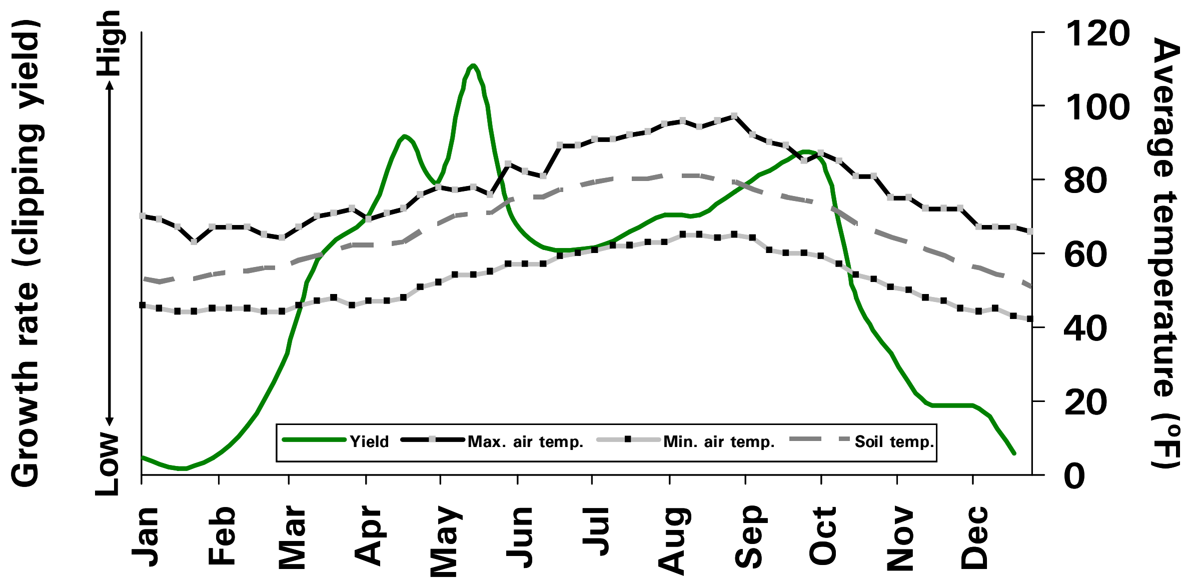
CHAPTER 5: PROJECT BACKGROUND AND INFORMATION

Table 6. Tall fescue visual turfgrass quality as influenced by annual nitrogen rate.

Annual average visual turfgrass quality[z]	Pounds N/1000 ft^2 per year	Use characteristics
–	7.0 to 8.0	–
6.5 to 7.5	6.0	Quality lawns, parks, recreational fields, and commercial areas
5.5 to 6.0	4.0	Acceptable lawns, parks, and recreational fields
–	0	–

[z]1 to 9 scale, 1 = dead or brown, 5 = minimally acceptable, and 9 = best tall fescue. Ranges based on field data.

Figure 3. Seasonal clipping yield growth pattern of tall fescue and average weekly maximum and minimum air temperatures and average weekly soil temperatures (6-inch depth) (1994-2001) in Riverside, Calif.



Note: Growth rate based on clipping yield data from six research projects conducted between 1994 and 2001. Average temperatures based on weekly averages of daily temperatures generated from on-site CIMIS station from January 1994 to December 2001. CIMIS data retrieved from http://www.cimis.water.ca.gov/.

Table 7. Fast- and slow-release nitrogen carriers.

I. Fast-release nitrogen carriers
    A. Inorganic Salts
        1. Ammonium nitrate
        2. Ammonium sulfate
        3. Potassium nitrate
        4. Many more
    B. Organic carriers
        1. Urea
        2. Methylol ureas

II. Slow-release nitrogen carriers
    A. Natural organics
        1. Bone meal
        2. Activated sewage sludge (Milorganic)
        3. Other materials
    B. Synthetic Organics
        1. Longer chained urea formaldehyde reaction products
            a) Nitroform
            b) Hydoform
        2. Shorter chained urea formaldehyde reaction products
            a) Hydrolene
            b) Nutralene
            c) Triaform
        3. Isobutylidene diurea (IBDU)
        4. Oxamide
        5. Triazone
        6. Others
    C. Coated Fertilizers
        1. Sulfur coated urea (SCU)
            a) Several products
        2. Polymer coated SCU's
            a) TriKote
            b) Poly S
            c) Poly Plus
            d) Others
        3. Polymer coated fertilizers
            a) ESN
            b) Once
            c) Polyon
            d) Multicote
            e) Others

Table 8. Parameters which affect mechanisms of nitrogen release among different slow-release fertilizers.

Fertilizer	Temperature	Bacterial	Moisture	pH	Particle size	Coating characteristic Thickness	Coating characteristic Chemical composition	Coating characteristic Durability
Natural organics	High to very high	Very high	High	Slight	Moderate	–	–	–
Longer chained UF	High to very high	High to very high	Slight	Slight	None	–	–	–
Shorter chained UF	Moderate to high	Moderate	Moderate	Slight	Slight	–	–	–
Isobutylidene diurea	Slight to moderate	Slight	High	Slight to moderate	Very high	–	–	–
Polymer coated sulfur coated urea	Moderate	Slight	Moderate	None	Moderate	Moderate	Moderate	High
Polymer coated fertilizers	High	None	Slight	None	High	High	Moderate to high	High

Harada, G., A. Van Peter, K. Parkins, and R. Green. 1995. Nitrogen fertilization: Slow release nitrogen fertilizers. Turf Tales Mag. 2(3):4,6-9.

Table 9. Agronomic considerations for slow- and fast-release nitrogen fertilizers.

Agronomic situation	Best choice	Worst choice
Sandy soil	Slow release	Fast release
Cold temperatures	Inorganic salts (nitrate)	Slow release
Warm temperatures	Slow release	Inorganic salts (nitrate)
Groundwater issues	Slow release	Fast release
Extended release	Slow release	Fast release
Tight turf canopy	Fast release or small particles of slow release	Large particles of slow release

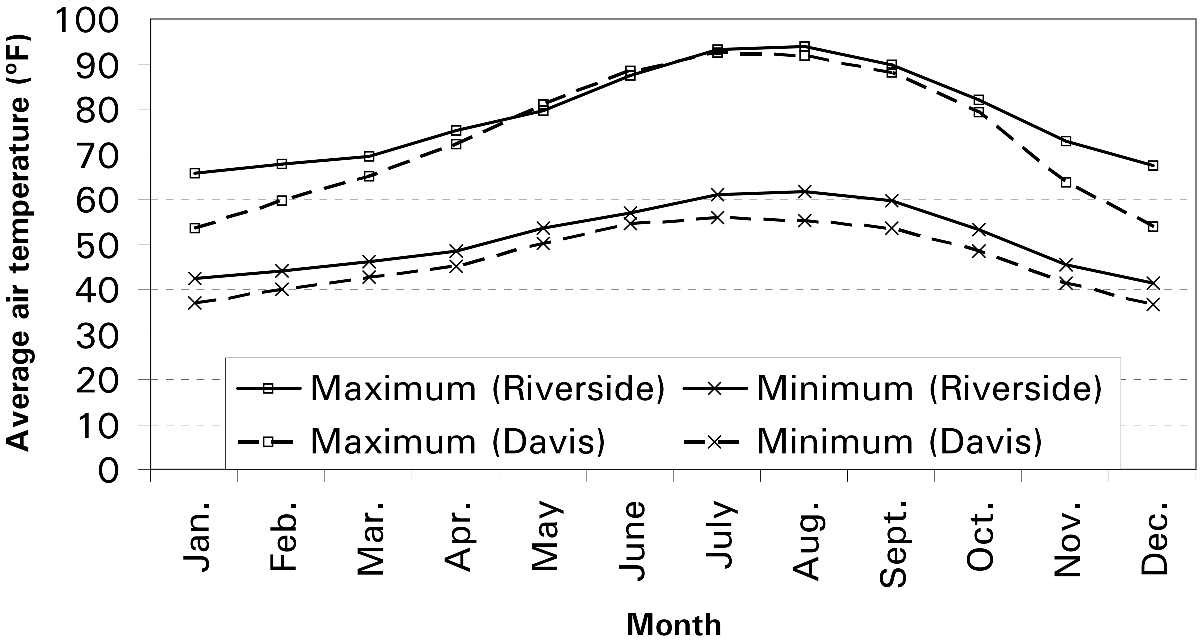
Harada, G., A. Van Peter, K. Parkins, and R. Green. 1995. Nitrogen fertilization: Slow release nitrogen fertilizers. Turf Tales Mag. 2(3):4,6-9.

Table 10. Operational considerations for slow- and fast-release nitrogen fertilizers.

Agronomic situation	Best choice	Worst choice
Minimal budget	Fast release	–
Low-skilled employees	Slow release	Fast release
Irrigation scheduling:		
Lack of water	Slow release	Fast release
Too much water	Slow release	Fast release
Decreased staffing levels	Slow release	Fast release

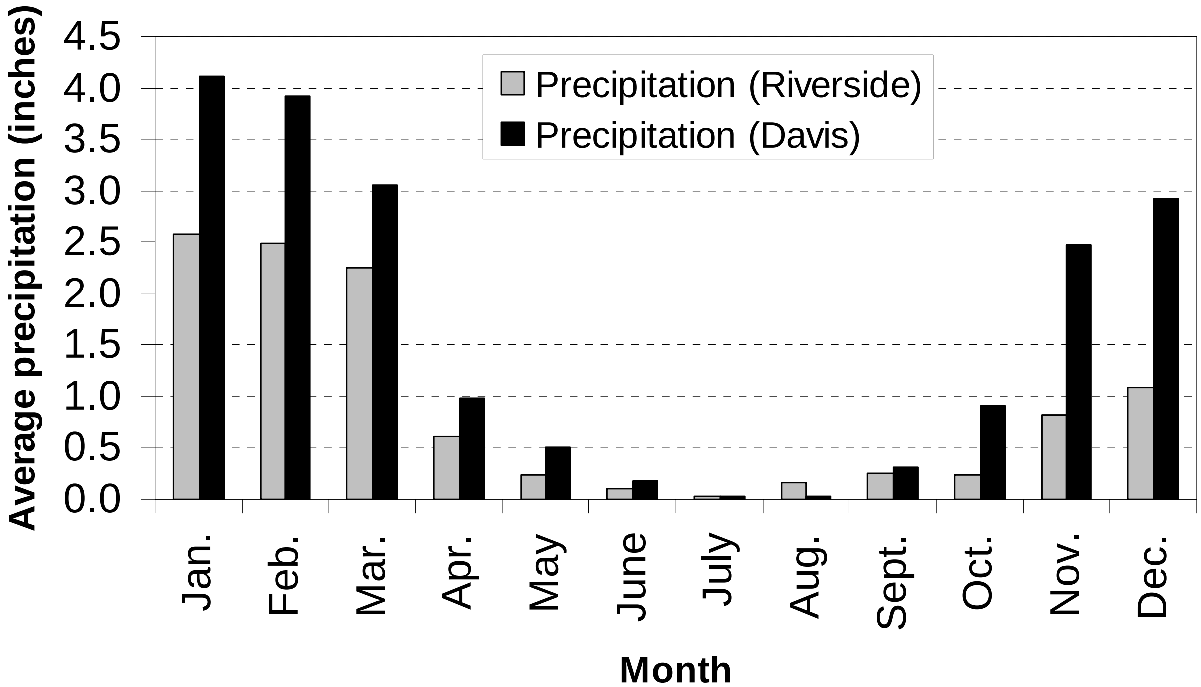
Harada, G., A. Van Peter, K. Parkins, and R. Green. 1995. Nitrogen fertilization: Slow release nitrogen fertilizers. Turf Tales Mag. 2(3):4,6-9.

Figure 4. Monthly average maximum and minimum air temperatures over 30 years (1972-2001) for Riverside and Davis, Calif.



Note: 30-year averages calculated from the National Oceanic and Atmospheric Administration (NOAA) Annual Climatological Summary data for 1972 through 2001 for the Riverside Citrus Experiment Station and the Davis Experimental Farm, dynamically generated via http://lwf.ncdc.noaa.gov/servlets/ACS.

Figure 5. Monthly average precipitation over 30 years (1972-2001) for Riverside and Davis, Calif.



Note: 30-year averages calculated from the National Oceanic and Atmospheric Administration (NOAA) Annual Climatological Summary data for 1972 through 2001 for the Riverside Citrus Experiment Station and the Davis Experimental Farm, dynamically generated via http://lwf.ncdc.noaa.gov/servlets/ACS.

Table 11. Historical ET_o, historical 30-year monthly average maximum and minimum air temperatures, and 30-year monthly average precipitation.

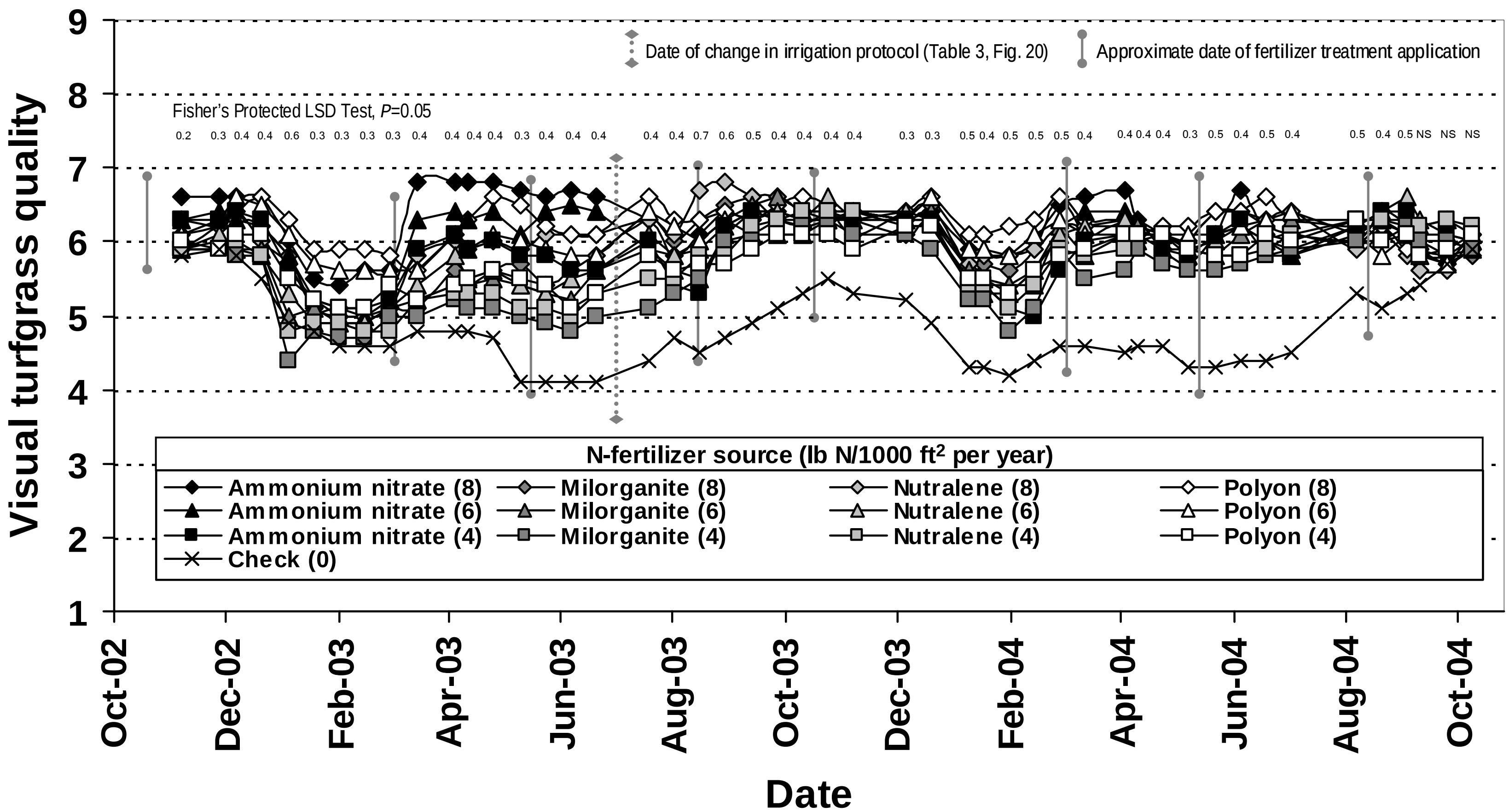
	Historical ET_o[z]		Historical air temperature[y]				Historical precipitation[y]	
			Maximum		Minimum			
Month	Riverside	Davis	Riverside	Davis	Riverside	Davis	Riverside	Davis
	--------- *inches* ----------		----------------- *ºF* -----------------				---------- *inches* -----------	
January	2.07	0.98	65.9	53.4	42.4	37.1	2.57	4.11
February	2.87	1.87	67.9	59.8	44.2	40.1	2.49	3.92
March	4.03	3.30	69.4	64.9	46.0	42.7	2.26	3.05
April	4.13	4.96	75.4	72.1	48.6	45.2	0.61	0.98
May	6.10	6.35	79.8	80.9	53.4	50.3	0.24	0.50
June	7.09	7.56	87.4	88.4	57.0	54.7	0.10	0.18
July	7.93	8.18	93.2	92.7	61.2	56.0	0.03	0.03
August	7.57	7.08	93.8	91.7	61.9	55.1	0.17	0.04
September	6.14	5.43	89.8	88.1	59.5	53.5	0.26	0.31
October	4.15	4.03	82.1	79.2	53.3	48.4	0.24	0.91
November	2.60	1.77	73.0	63.7	45.5	41.2	0.82	2.47
December	1.95	0.98	67.4	54.0	41.5	36.6	1.09	2.92
Annual	56.63	52.49	78.7	74.2	51.2	46.7	10.96	19.18

[z]Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of California, Division of Agricultural and Natural Resources. Publ. 21454.

[y]30-year averages calculated from the National Oceanic and Atmospheric Administration (NOAA) Annual Climatological Summary data for 1972 through 2001 for the Riverside Citrus Experiment Station and the Davis Experimental Farm, dynamically generated via http://lwf.ncdc.noaa.gov/servlets/ACS.

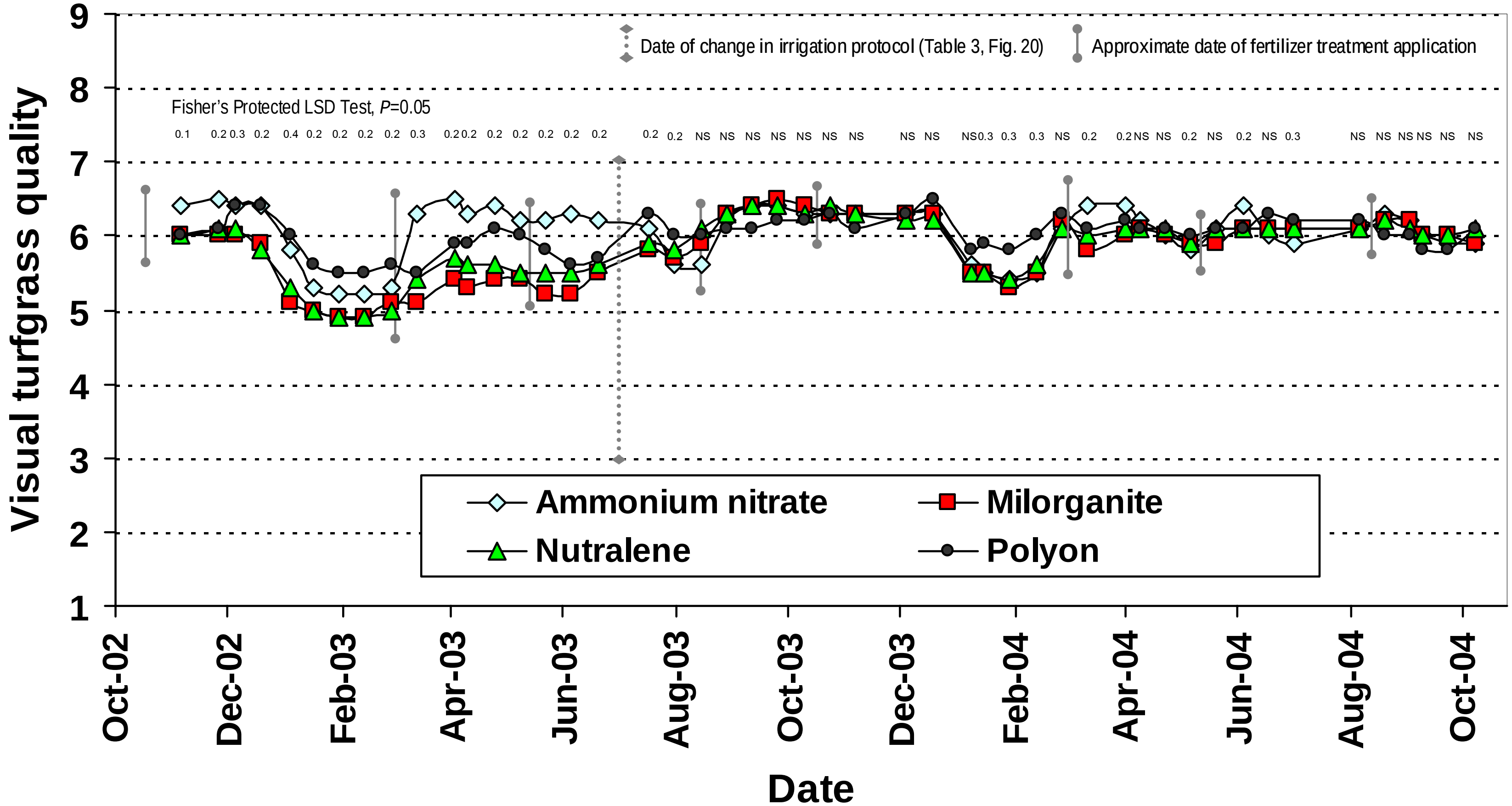
CHAPTER 6:
DATA TABLES AND FIGURES AND RELATED INFORMATION – UC RIVERSIDE

Figure 6. The effect of 13 treatments on visual turfgrass quality of tall fescue, 6 Nov. 2002 to 8 Oct. 2004.



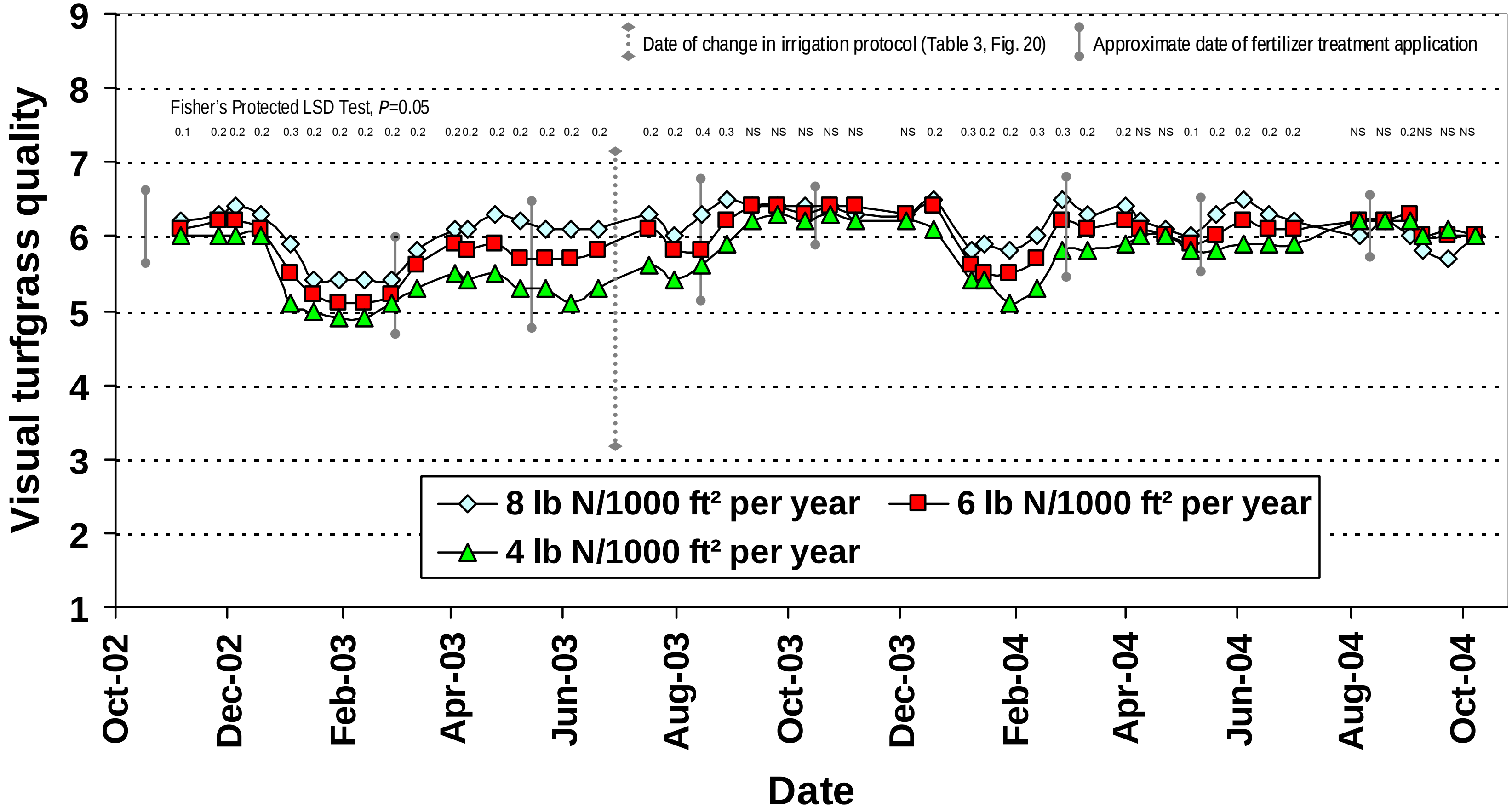
Visual Turfgrass Quality
1 = Brown/dead tall fescue
5 = Minimally acceptable tall fescue
9 = Best tall fescue

Figure 7. The effect of four N-fertilizer sources on visual turfgrass quality of tall fescue, 6 Nov. 2002 to 8 Oct. 2004. Means are the average of three N-fertilizer rates.



Visual Turfgrass Quality
1 = Brown/dead tall fescue
5 = Minimally acceptable tall fescue
9 = Best tall fescue

Figure 8. The effect of three N-fertilizer rates on visual turfgrass quality of tall fescue, 6 Nov. 2002 to 8 Oct. 2004. Means are the average of four N-fertilizer sources.



Visual Turfgrass Quality
1 = Brown/dead tall fescue
5 = Minimally acceptable tall fescue
9 = Best tall fescue

Table 12.1. The effect of N-fertility source and rate on visual turfgrass quality of tall fescue from Nov. 2002 to Apr. 2003 (1 to 9 scale, with 1 = worst, 5 = minimally acceptable, and 9 = best tall fescue).

Treatment		6 Nov. 2002	27 Nov. 2002	6 Dec. 2002	20 Dec. 2002	4 Jan. 2003	17 Jan. 2003	31 Jan. 2003	14 Feb. 2003	28 Feb. 2003	14 Mar. 2003	4 Apr. 2003	11 Apr. 2003
						ANOVA, RCB design, 13 treatments							
Source[z]	Rate[y]												
Ammonium nitrate	8	6.6	6.6	6.6	6.6	6.0	5.5	5.4	5.6	5.6	6.8	6.8	6.8
Milorganite	8	6.3	6.2	6.3	6.2	5.8	5.1	5.1	5.0	5.1	5.1	5.6	5.4
Nutralene	8	6.1	6.2	6.4	6.0	5.7	5.1	5.0	5.0	5.1	5.8	6.0	5.9
Polyon	8	5.9	6.2	6.4	6.6	6.3	5.9	5.9	5.9	5.8	5.6	6.1	6.3
Ammonium nitrate	6	6.3	6.4	6.3	6.2	5.8	5.2	5.0	5.0	5.2	6.3	6.4	6.3
Milorganite	6	5.9	6.0	5.9	5.9	5.0	5.1	4.9	4.9	5.1	5.2	5.4	5.4
Nutralene	6	5.9	6.1	5.9	5.8	5.3	4.9	4.9	4.9	5.1	5.4	5.8	5.5
Polyon	6	6.1	6.3	6.6	6.5	6.1	5.7	5.6	5.6	5.6	5.6	6.1	5.9
Ammonium nitrate	4	6.3	6.3	6.4	6.3	5.6	5.2	5.1	5.1	5.2	5.9	6.1	5.9
Milorganite	4	5.9	5.9	5.8	5.8	4.4	4.8	4.7	4.7	5.0	5.0	5.2	5.1
Nutralene	4	5.9	5.9	6.0	5.8	4.8	4.9	4.9	4.8	4.8	5.2	5.3	5.3
Polyon	4	6.0	5.9	6.1	6.1	5.5	5.2	5.1	5.1	5.4	5.2	5.4	5.5
Check	0	5.8	5.9	5.8	5.5	4.9	4.8	4.6	4.6	4.6	4.8	4.8	4.8
LSD, $P = 0.05$[x]		0.2	0.3	0.4	0.4	0.6	0.3	0.3	0.3	0.3	0.4	0.4	0.4
Randomized complete block design effects (*P*)													
Treatment		<0.0001	0.0008	0.0013	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
						ANOVA, 4 × 3 factorial design, 12 treatments							
Source[z]													
Ammonium nitrate		6.4	6.5	6.4	6.4	5.8	5.3	5.2	5.2	5.3	6.3	6.5	6.3
Milorganite		6.0	6.0	6.0	5.9	5.1	5.0	4.9	4.9	5.1	5.1	5.4	5.3
Nutralene		6.0	6.1	6.1	5.8	5.3	5.0	4.9	4.9	5.0	5.4	5.7	5.6
Polyon		6.0	6.1	6.4	6.4	6.0	5.6	5.5	5.5	5.6	5.5	5.9	5.9
LSD, $P = 0.05$[x]		0.1	0.2	0.3	0.2	0.4	0.2	0.2	0.2	0.2	0.3	0.2	0.2
Rate[y]													
8		6.2	6.3	6.4	6.3	5.9	5.4	5.4	5.4	5.4	5.8	6.1	6.1
6		6.1	6.2	6.2	6.1	5.5	5.2	5.1	5.1	5.2	5.6	5.9	5.8
4		6.0	6.0	6.0	6.0	5.1	5.0	4.9	4.9	5.1	5.3	5.5	5.4
LSD, $P = 0.05$[x]		0.1	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Factorial design effects (*P*)													
Source (S)		<0.0001	0.0005	0.0061	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Rate (R)		0.0008	0.0070	0.0045	0.0018	<0.0001	0.0002	0.0002	<0.0001	0.0011	0.0004	<0.0001	<0.0001
S x R		0.0049	0.8571	0.2502	0.6590	0.4094	0.1474	0.0538	0.0313	0.5714	0.1984	0.4560	0.5921

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P = 0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 12.2. The effect of N-fertility source and rate on visual turfgrass quality of tall fescue from Apr. to Oct. 2003 (1 to 9 scale, with 1 = worst, 5 = minimally acceptable, and 9 = best tall fescue).

Treatment		25 Apr. 2003	9 May 2003	23 May 2003	6 June 2003	20 June 2003	18 July 2003	1 Aug. 2003	15 Aug. 2003	29 Aug. 2003	12 Sept. 2003	26 Sept. 2003	10 Oct. 2003
ANOVA, RCB design, 13 treatments													
Source[z]	Rate[y]												
Ammonium nitrate	8	6.8	6.7	6.6	6.7	6.6	6.3	5.8	6.1	6.4	6.3	6.4	6.3
Milorganite	8	5.6	5.7	5.4	5.6	5.8	6.3	6.0	6.3	6.5	6.6	6.6	6.4
Nutralene	8	6.0	5.9	6.1	6.1	6.1	6.3	6.1	6.7	6.8	6.6	6.3	6.2
Polyon	8	6.6	6.5	6.2	6.1	6.1	6.6	6.3	6.3	6.4	6.3	6.5	6.6
Ammonium nitrate	6	6.4	6.1	6.4	6.5	6.4	5.9	5.6	5.5	6.1	6.4	6.4	6.3
Milorganite	6	5.5	5.4	5.3	5.2	5.6	6.1	5.8	6.0	6.3	6.5	6.6	6.4
Nutralene	6	5.6	5.4	5.3	5.5	5.6	5.9	5.8	5.9	6.2	6.4	6.4	6.3
Polyon	6	6.1	6.0	5.9	5.8	5.8	6.4	6.2	6.0	6.3	6.1	6.1	6.1
Ammonium nitrate	4	6.0	5.8	5.8	5.6	5.6	6.0	5.4	5.3	6.2	6.4	6.3	6.2
Milorganite	4	5.1	5.0	4.9	4.8	5.0	5.1	5.3	5.5	6.0	6.1	6.3	6.3
Nutralene	4	5.3	5.1	5.1	5.0	5.3	5.5	5.5	5.8	5.8	6.2	6.3	6.4
Polyon	4	5.6	5.5	5.4	5.1	5.3	5.8	5.6	5.7	5.7	5.9	6.1	6.1
Check	0	4.7	4.1	4.1	4.1	4.1	4.4	4.7	4.5	4.7	4.9	5.1	5.3
LSD, $P = 0.05$[x]		0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.7	0.6	0.5	0.4	0.4
Randomized complete block design effects (P)													
Treatment		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
ANOVA, 4 × 3 factorial design, 12 treatments													
Source[z]													
Ammonium nitrate		6.4	6.2	6.2	6.3	6.2	6.1	5.6	5.6	6.2	6.4	6.4	6.3
Milorganite		5.4	5.4	5.2	5.2	5.5	5.8	5.7	5.9	6.3	6.4	6.5	6.4
Nutralene		5.6	5.5	5.5	5.5	5.6	5.9	5.8	6.1	6.3	6.4	6.4	6.3
Polyon		6.1	6.0	5.8	5.6	5.7	6.3	6.0	6.0	6.1	6.1	6.2	6.2
LSD, $P = 0.05$[x]		0.2	0.2	0.2	0.2	0.2	0.2	0.2	NS	NS	NS	NS	NS
Rate[y]													
8		6.3	6.2	6.1	6.1	6.1	6.3	6.0	6.3	6.5	6.4	6.4	6.4
6		5.9	5.7	5.7	5.7	5.8	6.1	5.8	5.8	6.2	6.4	6.4	6.3
4		5.5	5.3	5.3	5.1	5.3	5.6	5.4	5.6	5.9	6.2	6.3	6.2
LSD, $P = 0.05$[x]		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.3	NS	NS	NS
Factorial design effects (P)													
Source (S)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0034	0.0030	0.1141	0.7896	0.1147	0.1269	0.5519
Rate (R)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0003	0.0005	0.0713	0.1554	0.3343
S x R		0.5461	0.8697	0.2248	0.4609	0.6295	0.0955	0.7689	0.9405	0.4733	0.7892	0.4232	0.1576

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P = 0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 12.3. The effect of N-fertility source and rate on visual turfgrass quality of tall fescue from Oct. 2003 to Apr. 2004 (1 to 9 scale, with 1 = worst, 5 = minimally acceptable, and 9 = best tall fescue).

Treatment		24 Oct. 2003	7 Nov. 2003	5 Dec. 2003	19 Dec. 2003	9 Jan. 2004	16 Jan. 2004	30 Jan. 2004	13 Feb. 2004	27 Feb. 2004	12 Mar. 2004	2 Apr. 2004	9 Apr. 2004
						ANOVA, RCB design, 13 treatments							
Source[z]	Rate[y]												
Ammonium nitrate	8	6.3	6.3	6.3	6.4	5.9	5.8	5.8	6.0	6.5	6.6	6.7	6.3
Milorganite	8	6.4	6.4	6.4	6.5	5.6	5.7	5.6	5.9	6.6	6.1	6.3	6.2
Nutralene	8	6.3	6.3	6.1	6.3	5.7	5.8	5.8	5.9	6.2	6.2	6.2	6.1
Polyon	8	6.5	6.1	6.4	6.6	6.1	6.1	6.2	6.3	6.6	6.3	6.3	6.1
Ammonium nitrate	6	6.3	6.4	6.3	6.3	5.6	5.4	5.4	5.6	6.2	6.4	6.4	6.3
Milorganite	6	6.3	6.4	6.3	6.4	5.6	5.5	5.4	5.4	6.2	5.8	6.1	6.2
Nutralene	6	6.6	6.3	6.4	6.3	5.4	5.3	5.3	5.6	6.1	6.2	6.3	6.1
Polyon	6	6.3	6.4	6.3	6.6	5.9	5.9	5.8	6.1	6.3	6.1	6.1	6.0
Ammonium nitrate	4	6.4	6.3	6.3	6.3	5.4	5.4	5.1	5.0	5.6	6.0	6.1	6.1
Milorganite	4	6.3	6.1	6.1	5.9	5.2	5.2	4.8	5.1	5.9	5.5	5.6	5.9
Nutralene	4	6.4	6.4	6.2	6.2	5.4	5.4	5.1	5.4	5.9	5.8	5.9	6.1
Polyon	4	6.1	5.9	6.2	6.2	5.5	5.5	5.3	5.6	5.8	5.9	6.1	6.1
Check	0	5.5	5.3	5.2	4.9	4.3	4.3	4.2	4.4	4.6	4.6	4.5	4.6
LSD, $P = 0.05$[x]		0.4	0.4	0.3	0.3	0.5	0.4	0.5	0.5	0.5	0.4	0.4	0.4
Randomized complete block design effects (P)													
Treatment		0.0004	0.0005	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
						ANOVA, 4 × 3 factorial design, 12 treatments							
Source[z]													
Ammonium nitrate		6.3	6.3	6.3	6.3	5.6	5.5	5.4	5.5	6.1	6.4	6.4	6.2
Milorganite		6.3	6.3	6.3	6.3	5.5	5.5	5.3	5.5	6.2	5.8	6.0	6.1
Nutralene		6.4	6.3	6.2	6.2	5.5	5.5	5.4	5.6	6.1	6.0	6.1	6.1
Polyon		6.3	6.1	6.3	6.5	5.8	5.9	5.8	6.0	6.3	6.1	6.2	6.1
LSD, $P = 0.05$[x]		NS	NS	NS	NS	NS	0.3	0.3	0.3	NS	0.2	0.2	NS
Rate[y]													
8		6.4	6.3	6.3	6.5	5.8	5.9	5.8	6.0	6.5	6.3	6.4	6.2
6		6.4	6.4	6.3	6.4	5.6	5.5	5.5	5.7	6.2	6.1	6.2	6.1
4		6.3	6.2	6.2	6.1	5.4	5.4	5.1	5.3	5.8	5.8	5.9	6.0
LSD, $P = 0.05$[x]		NS	NS	NS	0.2	0.3	0.2	0.2	0.3	0.3	0.2	0.2	NS
Factorial design effects (P)													
Source (S)		0.7172	0.3111	0.7887	0.1024	0.1312	0.0212	0.0103	0.0084	0.5175	0.0002	0.0077	0.5955
Rate (R)		0.7713	0.1303	0.1030	0.0015	0.0069	0.0006	<0.0001	<0.0001	<0.0001	<0.0001	0.0003	0.4286
S x R		0.2626	0.4868	0.2787	0.2127	0.8489	0.6054	0.8445	0.7376	0.7620	0.8513	0.4015	0.6307

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P = 0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 12.4. The effect of N-fertility source and rate on visual turfgrass quality of tall fescue from Apr. to Oct. 2004 (1 to 9 scale, with 1 = worst, 5 = minimally acceptable, and 9 = best tall fescue).

Treatment		23 Apr. 2004	7 May 2004	21 May 2004	4 June 2004	18 June 2004	2 July 2004	6 Aug. 2004	20 Aug. 2004	3 Sept. 2004	10 Sept. 2004	24 Sept. 2004	8 Oct. 2004
ANOVA, RCB design, 13 treatments													
Source[z]	Rate[y]												
Ammonium nitrate	8	5.9	5.7	6.1	6.7	6.1	6.1	6.0	6.2	6.1	5.9	5.7	5.9
Milorganite	8	6.1	6.0	6.4	6.4	6.2	6.1	6.0	6.4	6.2	5.9	5.8	5.8
Nutralene	8	6.1	6.0	6.4	6.4	6.3	6.4	5.9	6.1	5.8	5.6	5.6	6.1
Polyon	8	6.2	6.2	6.4	6.4	6.6	6.3	6.2	6.2	5.9	5.8	5.8	6.1
Ammonium nitrate	6	6.1	5.8	6.1	6.2	6.0	5.8	6.1	6.3	6.2	6.0	5.8	5.9
Milorganite	6	6.1	5.9	5.8	6.1	6.3	6.3	6.3	6.3	6.3	6.2	6.3	6.1
Nutralene	6	5.9	5.9	6.0	6.2	6.0	5.9	6.2	6.4	6.6	6.3	6.1	6.0
Polyon	6	6.1	6.1	6.1	6.2	6.3	6.4	6.1	5.8	6.1	5.8	5.7	6.1
Ammonium nitrate	4	5.9	5.8	6.1	6.3	5.8	5.8	6.2	6.4	6.4	6.1	6.1	6.0
Milorganite	4	5.7	5.6	5.6	5.7	5.8	5.9	6.0	6.0	6.2	6.0	6.0	5.9
Nutralene	4	6.1	5.9	5.8	5.8	5.9	6.1	6.3	6.3	6.1	6.2	6.3	6.2
Polyon	4	6.1	5.9	5.8	5.8	6.1	6.0	6.3	6.0	6.1	5.8	5.9	6.1
Check	0	4.6	4.3	4.3	4.4	4.4	4.5	5.3	5.1	5.3	5.4	5.7	5.9
LSD, $P = 0.05$[x]		0.4	0.3	0.5	0.4	0.5	0.4	0.5	0.4	0.5	NS	NS	NS
Randomized complete block design effects (P)													
Treatment		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0083	<0.0001	0.0021	0.1049	0.2470	0.8263
ANOVA, 4 × 3 factorial design, 12 treatments													
Source[z]													
Ammonium nitrate		6.0	5.8	6.1	6.4	6.0	5.9	6.1	6.3	6.2	6.0	5.9	5.9
Milorganite		6.0	5.9	5.9	6.1	6.1	6.1	6.1	6.2	6.2	6.0	6.0	5.9
Nutralene		6.1	5.9	6.1	6.1	6.1	6.1	6.1	6.2	6.1	6.0	6.0	6.1
Polyon		6.1	6.0	6.1	6.1	6.3	6.2	6.2	6.0	6.0	5.8	5.8	6.1
LSD, $P = 0.05$[x]		NS	0.2	NS	0.2	NS	0.3	NS	NS	NS	NS	NS	NS
Rate[y]													
8		6.1	6.0	6.3	6.5	6.3	6.2	6.0	6.2	6.0	5.8	5.7	6.0
6		6.0	5.9	6.0	6.2	6.1	6.1	6.2	6.2	6.3	6.0	6.0	6.0
4		6.0	5.8	5.8	5.9	5.9	5.9	6.2	6.2	6.2	6.0	6.1	6.0
LSD, $P = 0.05$[x]		NS	0.1	0.2	0.2	0.2	0.2	NS	NS	0.2	NS	NS	NS
Factorial design effects (P)													
Source (S)		0.2456	0.0102	0.6425	0.0137	0.0828	0.0455	0.9319	0.0639	0.2528	0.2150	0.4585	0.3128
Rate (R)		0.2560	0.0308	0.0007	<0.0001	0.0095	0.0419	0.2906	0.7817	0.0215	0.1365	0.0796	0.7029
S x R		0.2252	0.4166	0.4799	0.3737	0.9372	0.4728	0.6376	0.0671	0.0287	0.6094	0.4367	0.8689

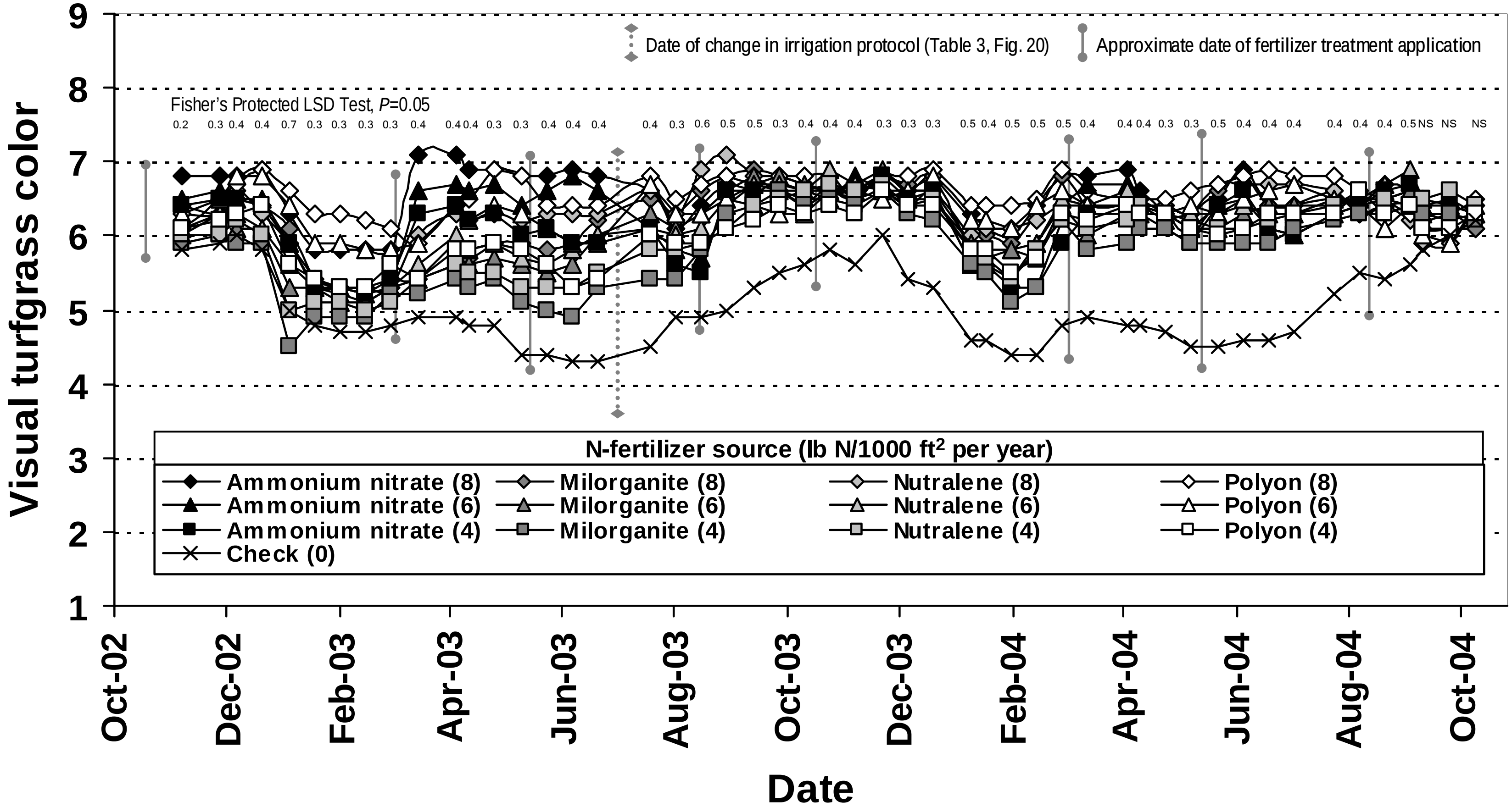
[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P = 0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Figure 9. The effect of 13 treatments on visual turfgrass color of tall fescue, 6 Nov. 2002 to 8 Oct. 2004.



Visual Turfgrass Color
1 = Brown tall fescue
5 = Minimally acceptable tall fescue
9 = Darkest green tall fescue

Figure 10. The effect of four N-fertilizer sources on visual turfgrass color of tall fescue, 6 Nov. 2002 to 8 Oct. 2004. Means are the average of three N-fertilizer rates.

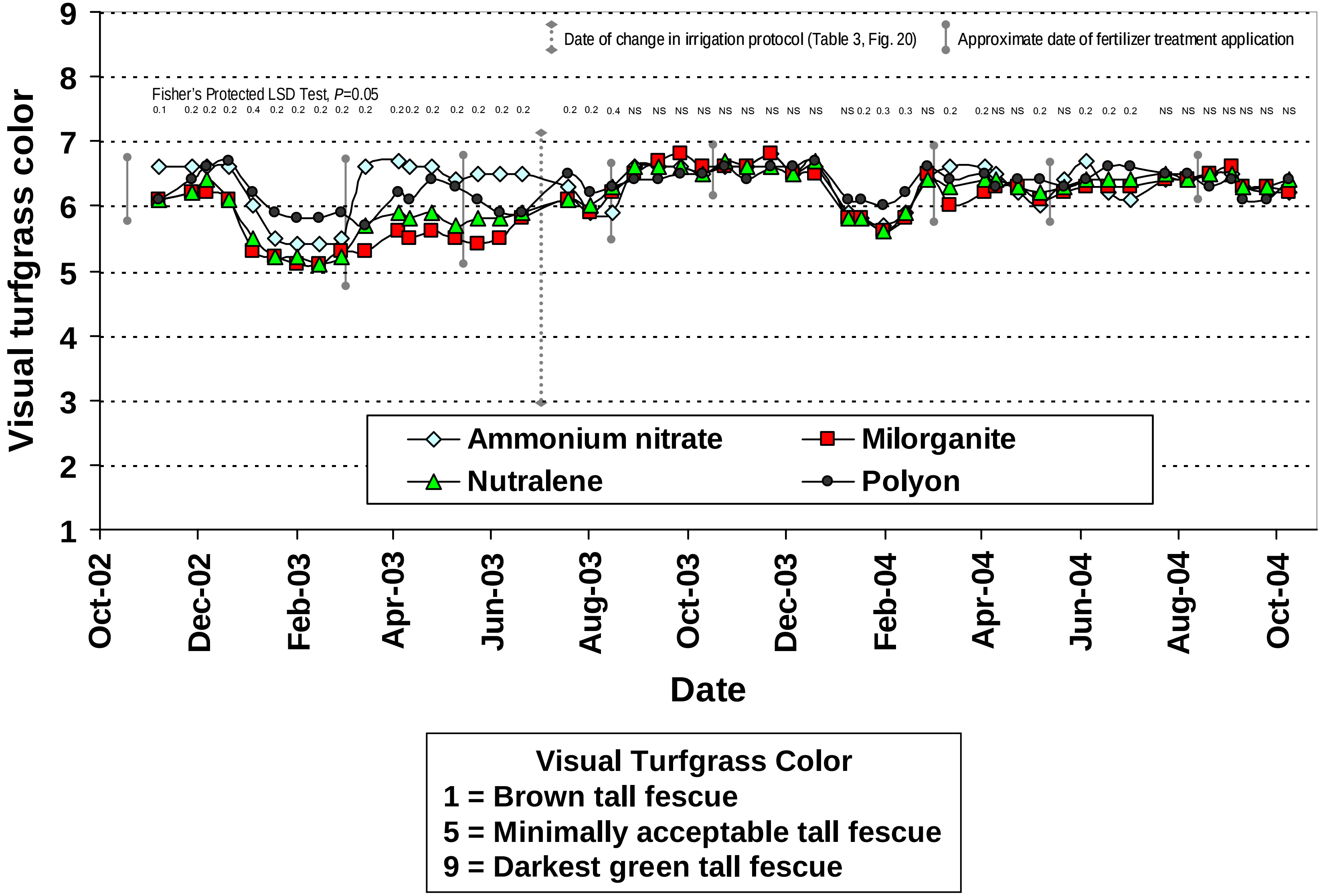
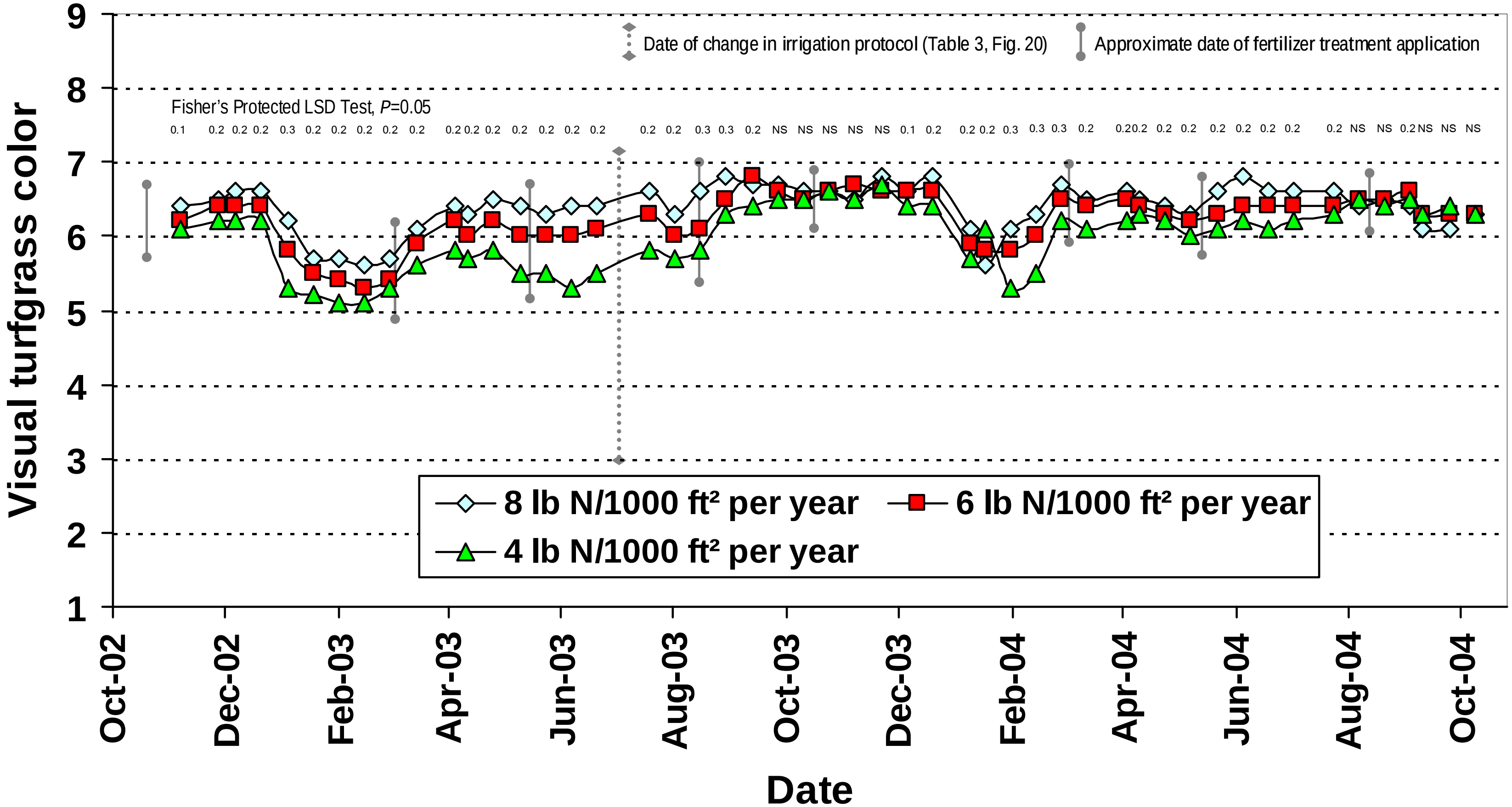


Figure 11. The effect of three N-fertilizer rates on visual turfgrass color of tall fescue, 6 Nov. 2002 to 8 Oct. 2004. Means are the average of four N-fertilizer sources.



Visual Turfgrass Color
1 = Brown tall fescue
5 = Minimally acceptable tall fescue
9 = Darkest green tall fescue

Table 13.1. The effect of N-fertility source and rate on visual turfgrass color of tall fescue from Nov. 2002 to Apr. 2003 (1 to 9 scale, with 1 = brown, 5 = minimally acceptable, and 9 = darkest green tall fescue).

Treatment		6 Nov. 2002	27 Nov. 2002	6 Dec. 2002	20 Dec. 2002	4 Jan. 2003	17 Jan. 2003	31 Jan. 2003	14 Feb. 2003	28 Feb. 2003	14 Mar. 2003	4 Apr. 2003	11 Apr. 2003
						ANOVA, RCB design, 13 treatments							
Source[z]	Rate[y]												
Ammonium nitrate	8	6.8	6.8	6.8	6.9	6.3	5.8	5.8	5.8	5.8	7.1	7.1	6.9
Milorganite	8	6.4	6.3	6.5	6.4	6.1	5.4	5.3	5.3	5.4	5.4	5.9	5.7
Nutralene	8	6.3	6.3	6.6	6.3	5.9	5.3	5.3	5.3	5.3	6.0	6.3	6.2
Polyon	8	6.1	6.5	6.7	6.9	6.6	6.3	6.3	6.2	6.1	5.9	6.4	6.5
Ammonium nitrate	6	6.5	6.6	6.5	6.5	5.9	5.4	5.3	5.2	5.3	6.6	6.7	6.6
Milorganite	6	6.1	6.3	6.1	6.1	5.3	5.3	5.1	5.1	5.3	5.4	5.6	5.6
Nutralene	6	6.0	6.3	6.3	6.1	5.6	5.3	5.2	5.1	5.3	5.6	6.0	5.8
Polyon	6	6.3	6.5	6.8	6.8	6.4	5.9	5.9	5.8	5.8	5.9	6.4	6.2
Ammonium nitrate	4	6.4	6.5	6.5	6.4	5.9	5.3	5.3	5.2	5.4	6.3	6.4	6.2
Milorganite	4	5.9	6.0	5.9	5.9	4.5	4.9	4.9	4.9	5.2	5.2	5.4	5.3
Nutralene	4	6.0	6.0	6.2	6.0	5.0	5.1	5.1	5.0	5.1	5.4	5.6	5.5
Polyon	4	6.1	6.2	6.3	6.4	5.6	5.4	5.3	5.3	5.6	5.4	5.8	5.8
Check	0	5.8	5.9	6.0	5.8	5.0	4.8	4.7	4.7	4.8	4.9	4.9	4.8
LSD, $P = 0.05$[x]		0.2	0.3	0.4	0.4	0.7	0.3	0.3	0.3	0.3	0.4	0.4	0.4
Randomized complete block design effects (P)													
Treatment		<0.0001	<0.0001	0.0005	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
						ANOVA, 4 × 3 factorial design, 12 treatments							
Source[z]													
Ammonium nitrate		6.6	6.6	6.6	6.6	6.0	5.5	5.4	5.4	5.5	6.6	6.7	6.6
Milorganite		6.1	6.2	6.2	6.1	5.3	5.2	5.1	5.1	5.3	5.3	5.6	5.5
Nutralene		6.1	6.2	6.4	6.1	5.5	5.2	5.2	5.1	5.2	5.7	5.9	5.8
Polyon		6.1	6.4	6.6	6.7	6.2	5.9	5.8	5.8	5.9	5.7	6.2	6.1
LSD, $P = 0.05$[x]		0.1	0.2	0.2	0.2	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Rate[y]													
8		6.4	6.5	6.6	6.6	6.2	5.7	5.7	5.6	5.7	6.1	6.4	6.3
6		6.2	6.4	6.4	6.4	5.8	5.5	5.4	5.3	5.4	5.9	6.2	6.0
4		6.1	6.2	6.2	6.2	5.3	5.2	5.1	5.1	5.3	5.6	5.8	5.7
LSD, $P = 0.05$[x]		0.1	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Factorial design effects (P)													
Source (S)		<0.0001	<0.0001	0.0026	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Rate (R)		<0.0001	0.0033	0.0014	0.0006	<0.0001	<0.0001	<0.0001	<0.0001	0.0004	<0.0001	<0.0001	<0.0001
S x R		0.0018	0.8518	0.4409	0.8555	0.2960	0.0885	0.0536	0.0790	0.2555	0.2503	0.4798	0.7867

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P = 0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 13.2. The effect of N-fertility source and rate on visual turfgrass color of tall fescue from Apr. to Oct. 2003 (1 to 9 scale, with 1 = brown, 5 = minimally acceptable, and 9 = darkest tall fescue).

Treatment		25 Apr. 2003	9 May 2003	23 May 2003	6 June 2003	20 June 2003	18 July 2003	1 Aug. 2003	15 Aug. 2003	29 Aug. 2003	12 Sept. 2003	26 Sept. 2003	10 Oct. 2003
ANOVA, RCB design, 13 treatments													
Source[z]	Rate[y]												
Ammonium nitrate	8	6.9	6.8	6.8	6.9	6.8	6.6	6.1	6.4	6.7	6.6	6.7	6.6
Milorganite	8	5.9	5.9	5.8	5.9	6.2	6.5	6.3	6.6	6.8	6.9	6.8	6.7
Nutralene	8	6.3	6.2	6.3	6.3	6.3	6.6	6.2	6.9	7.1	6.8	6.6	6.4
Polyon	8	6.9	6.8	6.4	6.4	6.4	6.8	6.5	6.7	6.8	6.7	6.8	6.8
Ammonium nitrate	6	6.7	6.4	6.6	6.8	6.6	6.1	5.8	5.7	6.4	6.7	6.6	6.6
Milorganite	6	5.7	5.6	5.5	5.6	6.0	6.3	6.1	6.3	6.6	6.8	6.8	6.7
Nutralene	6	5.9	5.7	5.6	5.8	6.0	6.1	6.0	6.1	6.5	6.7	6.7	6.6
Polyon	6	6.4	6.3	6.1	5.9	5.9	6.7	6.3	6.3	6.5	6.4	6.3	6.3
Ammonium nitrate	4	6.3	6.0	6.1	5.9	5.9	6.1	5.6	5.5	6.6	6.6	6.6	6.4
Milorganite	4	5.4	5.1	5.0	4.9	5.3	5.4	5.4	5.8	6.3	6.4	6.6	6.5
Nutralene	4	5.5	5.3	5.3	5.3	5.5	5.8	5.8	5.9	6.1	6.4	6.5	6.6
Polyon	4	5.9	5.8	5.6	5.3	5.4	6.0	5.9	5.9	6.1	6.2	6.4	6.3
Check	0	4.8	4.4	4.4	4.3	4.3	4.5	4.9	4.9	5.0	5.3	5.5	5.6
LSD, $P = 0.05$[x]		0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.6	0.5	0.5	0.3	0.4
Randomized complete block design effects (P)													
Treatment		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
ANOVA, 4 × 3 factorial design, 12 treatments													
Source[z]													
Ammonium nitrate		6.6	6.4	6.5	6.5	6.5	6.3	5.9	5.9	6.6	6.6	6.6	6.5
Milorganite		5.6	5.5	5.4	5.5	5.8	6.1	5.9	6.2	6.5	6.7	6.8	6.6
Nutralene		5.9	5.7	5.8	5.8	5.9	6.1	6.0	6.3	6.6	6.6	6.6	6.5
Polyon		6.4	6.3	6.1	5.9	5.9	6.5	6.2	6.3	6.4	6.4	6.5	6.5
LSD, $P = 0.05$[x]		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4	NS	NS	NS	NS
Rate[y]													
8		6.5	6.4	6.3	6.4	6.4	6.6	6.3	6.6	6.8	6.7	6.7	6.6
6		6.2	6.0	6.0	6.0	6.1	6.3	6.0	6.1	6.5	6.8	6.6	6.5
4		5.8	5.5	5.5	5.3	5.5	5.8	5.7	5.8	6.3	6.4	6.5	6.5
LSD, $P = 0.05$[x]		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.2	NS	NS
Factorial design effects (P)													
Source (S)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0026	0.0028	0.0493	0.8201	0.2532	0.0573	0.5079
Rate (R)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0006	0.0290	0.0872	0.1492
S x R		0.6072	0.8902	0.4855	0.8389	0.8969	0.1262	0.4440	0.9348	0.4200	0.6437	0.3563	0.1470

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P = 0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 13.3. The effect of N-fertility source and rate on visual turfgrass color of tall fescue from Oct. 2003 to Apr. 2004 (1 to 9 scale, with 1 = brown, 5 = minimally acceptable, and 9 = darkest tall fescue).

Treatment		24 Oct. 2003	7 Nov. 2003	21 Nov. 2003	5 Dec. 2003	19 Dec. 2003	9 Jan. 2004	16 Jan. 2004	30 Jan. 2004	13 Feb. 2004	27 Feb. 2004	12 Mar. 2004	2 Apr. 2004
ANOVA, RCB design, 13 treatments													
Source[z]	Rate[y]												
Ammonium nitrate	8	6.6	6.5	6.8	6.6	6.8	6.3	6.1	6.0	6.4	6.8	6.8	6.9
Milorganite	8	6.6	6.6	6.8	6.7	6.8	5.8	6.0	5.9	6.3	6.8	6.4	6.4
Nutralene	8	6.6	6.5	6.6	6.4	6.6	6.0	6.1	6.1	6.2	6.4	6.4	6.4
Polyon	8	6.8	6.5	6.8	6.8	6.9	6.4	6.4	6.4	6.5	6.9	6.6	6.5
Ammonium nitrate	6	6.5	6.8	6.6	6.5	6.5	5.9	5.7	5.8	5.9	6.4	6.7	6.7
Milorganite	6	6.6	6.7	6.9	6.6	6.6	5.9	5.8	5.8	5.7	6.4	6.0	6.3
Nutralene	6	6.9	6.7	6.6	6.6	6.6	5.6	5.6	5.4	5.9	6.5	6.4	6.6
Polyon	6	6.6	6.6	6.5	6.6	6.8	6.2	6.2	6.1	6.4	6.6	6.4	6.4
Ammonium nitrate	4	6.7	6.6	6.8	6.5	6.6	5.6	5.6	5.3	5.3	5.9	6.3	6.3
Milorganite	4	6.5	6.4	6.6	6.3	6.2	5.6	5.5	5.1	5.3	6.2	5.8	5.9
Nutralene	4	6.7	6.6	6.7	6.4	6.5	5.8	5.7	5.4	5.8	6.2	6.1	6.2
Polyon	4	6.4	6.3	6.6	6.4	6.4	5.8	5.8	5.5	5.7	6.3	6.2	6.4
Check	0	5.8	5.6	6.0	5.4	5.3	4.6	4.6	4.4	4.4	4.8	4.9	4.8
LSD, $P = 0.05$[x]		0.4	0.4	0.3	0.3	0.3	0.5	0.4	0.5	0.5	0.5	0.4	0.4
Randomized complete block design effects (*P*)													
Treatment		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
ANOVA, 4 × 3 factorial design, 12 treatments													
Source[z]													
Ammonium nitrate		6.6	6.6	6.8	6.5	6.6	5.9	5.8	5.7	5.9	6.4	6.6	6.6
Milorganite		6.6	6.6	6.8	6.5	6.5	5.8	5.8	5.6	5.8	6.5	6.0	6.2
Nutralene		6.7	6.6	6.6	6.5	6.7	5.8	5.8	5.6	5.9	6.4	6.3	6.4
Polyon		6.6	6.4	6.6	6.6	6.7	6.1	6.1	6.0	6.2	6.6	6.4	6.5
LSD, $P = 0.05$[x]		NS	NS	NS	NS	NS	NS	0.2	0.3	0.3	NS	0.2	0.2
Rate[y]													
8		6.6	6.5	6.8	6.6	6.8	6.1	5.6	6.1	6.3	6.7	6.5	6.6
6		6.6	6.7	6.6	6.6	6.6	5.9	5.8	5.8	6.0	6.5	6.4	6.5
4		6.6	6.5	6.7	6.4	6.4	5.7	6.1	5.3	5.5	6.2	6.1	6.2
LSD, $P = 0.05$[x]		NS	NS	NS	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.2
Factorial design effects (*P*)													
Source (S)		0.5816	0.2837	0.2270	0.6418	0.0775	0.0747	0.0119	0.0449	0.0389	0.3997	0.0002	0.0037
Rate (R)		0.6357	0.0664	0.1611	0.0149	0.0002	0.0025	0.0001	<0.0001	<0.0001	0.0006	<0.0001	0.0009
S x R		0.2127	0.7181	0.1050	0.1852	0.0974	0.3967	0.5836	0.6616	0.5213	0.7853	0.7847	0.3039

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P = 0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 13.4. The effect of N-fertility source and rate on visual turfgrass color of tall fescue from Apr. to Sept. 2004 (1 to 9 scale, with 1 = brown, 5 = minimally acceptable, and 9 = darkest tall fescue).

Treatment		9 Apr. 2004	23 Apr. 2004	7 May 2004	21 May 2004	4 June 2004	18 June 2004	2 July 2004	23 July 2004	6 Aug. 2004	20 Aug. 2004	3 Sept. 2004	10 Sept. 2004
ANOVA, RCB design, 13 treatments													
Source[z]	Rate[y]												
Ammonium nitrate	8	6.6	6.3	6.0	6.5	6.9	6.4	6.4	6.6	6.3	6.4	6.4	6.1
Milorganite	8	6.4	6.4	6.3	6.6	6.8	6.4	6.4	6.5	6.4	6.7	6.6	6.3
Nutralene	8	6.4	6.4	6.3	6.7	6.7	6.7	6.7	6.6	6.3	6.4	6.2	5.9
Polyon	8	6.5	6.5	6.6	6.7	6.8	6.9	6.8	6.8	6.6	6.5	6.3	6.2
Ammonium nitrate	6	6.5	6.3	6.1	6.4	6.5	6.1	6.0	6.3	6.4	6.5	6.6	6.3
Milorganite	6	6.4	6.3	6.2	6.1	6.3	6.4	6.4	6.4	6.5	6.5	6.6	6.4
Nutralene	6	6.4	6.2	6.3	6.3	6.4	6.3	6.3	6.5	6.5	6.7	6.9	6.5
Polyon	6	6.3	6.3	6.4	6.3	6.5	6.6	6.7	6.5	6.4	6.1	6.4	6.0
Ammonium nitrate	4	6.3	6.1	5.9	6.4	6.6	6.1	6.0	6.3	6.4	6.6	6.7	6.4
Milorganite	4	6.1	6.1	5.9	5.9	5.9	5.9	6.1	6.2	6.3	6.3	6.4	6.3
Nutralene	4	6.4	6.3	6.1	6.1	6.1	6.2	6.3	6.4	6.6	6.5	6.4	6.5
Polyon	4	6.3	6.3	6.1	6.0	6.1	6.3	6.3	6.3	6.6	6.3	6.4	6.1
Check	0	4.8	4.7	4.5	4.5	4.6	4.6	4.7	5.2	5.5	5.4	5.6	5.8
LSD, $P = 0.05$[x]		0.4	0.3	0.3	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.5	NS
Randomized complete block design effects (*P*)													
Treatment		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0022	<0.0001	0.0009	0.0812
ANOVA, 4 × 3 factorial design, 12 treatments													
Source[z]													
Ammonium nitrate		6.5	6.2	6.0	6.4	6.7	6.2	6.1	6.4	6.4	6.5	6.5	6.3
Milorganite		6.3	6.3	6.1	6.2	6.3	6.3	6.3	6.4	6.4	6.5	6.6	6.3
Nutralene		6.4	6.3	6.2	6.3	6.4	6.4	6.4	6.5	6.4	6.5	6.5	6.3
Polyon		6.3	6.4	6.4	6.3	6.4	6.6	6.6	6.5	6.5	6.3	6.4	6.1
LSD, $P = 0.05$[x]		NS	NS	0.2	NS	0.2	0.2	0.2	NS	NS	NS	NS	NS
Rate[y]													
8		6.5	6.4	6.3	6.6	6.8	6.6	6.6	6.6	6.4	6.5	6.4	6.1
6		6.4	6.3	6.2	6.3	6.4	6.4	6.4	6.4	6.5	6.5	6.6	6.3
4		6.3	6.2	6.0	6.1	6.2	6.1	6.2	6.3	6.5	6.4	6.5	6.3
LSD, $P = 0.05$[x]		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	NS	NS	0.2	NS
Factorial design effects (*P*)													
Source (S)		0.3377	0.5879	0.0009	0.4051	0.0138	0.0096	0.0049	0.2892	0.5973	0.0642	0.3052	0.3989
Rate (R)		0.0241	0.0333	0.0026	0.0002	<0.0001	0.0005	0.0012	0.0085	0.6996	0.4490	0.0498	0.1542
S x R		0.6869	0.7087	0.4107	0.5706	0.3991	0.5229	0.4446	0.8424	0.6896	0.0637	0.0498	0.2377

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P = 0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 13.5. The effect of N-fertility source and rate on visual turfgrass color of tall fescue from Sept. to Oct. 2004 (1 to 9 scale, with 1 = brown, 5 = minimally acceptable, and 9 = darkest tall fescue).

Treatment		24 Sept. 2004	08 Oct. 2004
ANOVA, RCB design, 13 treatments			
Source[z]	Rate[y]		
Ammonium nitrate	8	6.1	6.1
Milorganite	8	6.3	6.1
Nutralene	8	5.9	6.4
Polyon	8	6.3	6.5
Ammonium nitrate	6	6.2	6.3
Milorganite	6	6.5	6.3
Nutralene	6	6.4	6.3
Polyon	6	5.9	6.4
Ammonium nitrate	4	6.4	6.3
Milorganite	4	6.3	6.2
Nutralene	4	6.6	6.4
Polyon	4	6.1	6.3
Check	0	6.0	6.2
LSD, $P = 0.05$[x]		NS	NS
Randomized complete block design effects (*P*)			
Treatment		0.1352	0.7106
ANOVA, 4 × 3 factorial design, 12 treatments			
Source[z]			
Ammonium nitrate		6.2	6.2
Milorganite		6.3	6.2
Nutralene		6.3	6.4
Polyon		6.1	6.4
LSD, $P = 0.05$[x]		NS	NS
Rate[y]			
8		6.1	6.3
6		6.3	6.3
4		6.4	6.3
LSD, $P = 0.05$[x]		NS	NS
Factorial design effects (*P*)			
Source (S)		0.4457	0.1707
Rate (R)		0.1759	0.9466
S x R		0.1374	0.8076

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P = 0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 14. The effect of N-fertility source and rate on overall visual turfgrass quality (1 to 9 scale, with 1 = worst, 5 = minimally acceptable, and 9 = best tall fescue) and on overall visual turfgrass color (1 to 9 scale, with 1 = brown, 5 = minimally acceptable, and 9 = darkest tall fescue) of tall fescue from 6 Nov. 2002 to 8 Oct. 2004.

Treatment		Overall visual turfgrass quality	Overall visual turfgrass color
ANOVA, repeated measures of a RCB design, 13 treatments			
Source[z]	Rate[y]		
Ammonium nitrate	8	6.2	6.5
Milorganite	8	6.0	6.3
Nutralene	8	6.0	6.3
Polyon	8	6.2	6.6
Ammonium nitrate	6	6.0	6.3
Milorganite	6	5.8	6.1
Nutralene	6	5.9	6.2
Polyon	6	6.1	6.3
Ammonium nitrate	4	5.9	6.1
Milorganite	4	5.5	5.8
Nutralene	4	5.7	6.0
Polyon	4	5.8	6.0
Check	0	4.8	5.0
LSD, $P = 0.05$[x]		0.2	0.2
Repeated measures design effects (P)			
Treatment (T)		<0.0001	<0.0001
Date (D)		<0.0001	<0.0001
T x D		<0.0001	<0.0001
ANOVA, repeated measures of a 4 × 3 factorial design, 12 treatments			
Source[z]			
Ammonium nitrate		6.0	6.3
Milorganite		5.8	6.1
Nutralene		5.9	6.1
Polyon		6.0	6.3
LSD, $P = 0.05$[x]		0.1	0.1
Rate[x]			
8		6.1	6.4
6		5.9	6.2
4		5.7	6.0
LSD, $P = 0.05$[x]		0.1	0.1
Factorial repeated measures design effects (P)			
Source (S)		0.0073	0.0064
Rate (R)		0.0010	0.0003
S x R		0.6977	0.4437
Date (D)		<0.0001	<0.0001
D x S		<0.0001	<0.0001
D x R		<0.0001	<0.0001
D x S x R		0.2442	0.3444

[z] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y] Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P = 0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 15. The effect of N-fertility source and rate on the number of rating dates that tall fescue visual turfgrass quality was ≥ 5.0, ≥ 5.5, ≥ 6.0, and ≥ 6.5 (based on a 1 to 9 scale, with 1 = worst, 5 = minimally acceptable, and 9 = best tall fescue) from 6 Nov. 2002 to 8 Oct. 2004.

Treatment		6 Nov. 2002 to 10 Oct. 2003				24 Oct. 2003 to 8 Oct. 2004				6 Nov. 2002 to 8 Oct. 2004			
		≥ 5.0	≥ 5.5	≥ 6.0	≥ 6.5	≥ 5.0	≥ 5.5	≥ 6.0	≥ 6.5	≥ 5.0	≥ 5.5	≥ 6.0	≥ 6.5
		----------- *Total of 24 rating dates* -----------				----------- *Total of 24 rating dates* -----------				----------- *Total of 48 rating dates* -----------			
ANOVA, RCB design, 13 treatments													
Source[z]	Rate[y]												
Ammonium nitrate	8	24 a[x]	23 ab	19 a	12 a	24 a	24 a	16 ab	4 a	48 a	47 ab	35 ab	16 a
Milorganite	8	24 a	17 abc	11 abcd	3 ab	24 a	24 a	17 ab	2 a	48 a	41 abcd	28 abcd	5 abc
Nutralene	8	24 a	20 abc	16 abc	3 ab	24 a	24 a	16 ab	0 a	48 a	44 abc	32 abc	3 abc
Polyon	8	24 a	24 a	18 ab	6 ab	24 a	24 a	21 a	4 a	48 a	48 a	39 a	10 ab
Ammonium nitrate	6	24 a	20 abc	16 abc	1 b	24 a	22 a	16 ab	0 a	48 a	42 abcd	32 abc	1 bc
Milorganite	6	22 a	13 bcd	7 bcde	2 ab	24 a	22 a	17 ab	0 a	46 a	35 cd	24 abcd	2 bc
Nutralene	6	21 a	16 abc	5 cde	0 b	24 a	21 a	17 ab	2 a	45 a	37 bcd	22 bcd	2 bc
Polyon	6	24 a	24 a	15 abcd	2 ab	24 a	24 a	18 ab	1 a	48 a	48 a	33 abc	3 abc
Ammonium nitrate	4	24 a	18 abc	11 abcd	0 b	24 a	20 a	15 ab	0 a	48 a	38 bcd	26 abcd	0 c
Milorganite	4	18 a	9 cd	4 de	0 b	23 a	20 a	8 bc	0 a	41 a	29 d	12 d	0 c
Nutralene	4	19 a	11 cd	4 de	0 b	24 a	20 a	13 ab	0 a	43 a	31 cd	17 cd	0 c
Polyon	4	24 a	15 abcd	5 cde	0 b	24 a	23 a	12 ab	0 a	48 a	38 bcd	17 cd	0 c
Check	0	6 b	4 d	0 e	0 b	9 b	3 b	0 c	0 a	15 b	7 e	0 e	0 c
ANOVA, 4 × 3 factorial design, 12 treatments													
Source[z]													
Ammonium nitrate		24	20 a	17 a	2	24	23	16	0	48	43 a	33	2
Milorganite		22	12 b	7 a	1	24	23	16	0	46	35 b	23	1
Nutralene		22	18 a	8 a	0	24	23	19	0	46	41 a	27	0
Polyon		24	24 a	14 a	0	24	24	19	1	48	48 a	33	1
Rate[y]													
8		24	20 a	18 a	1	24	24 a	19 a	3	48	44 a	37 a	4
6		24	20 a	9 ab	0	24	24 a	19 a	0	48	44 a	28 ab	0
4		22	12 a	7 b	0	24	20 a	12 a	0	46	32 b	19 b	0

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's Exact Test (protected) and Chi-Square Test (protected), P = 0.05 or 0.10. Means followed by the same letter are not significantly different. Means not followed by letters are not significantly different and the treatment effect is not significant.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 16. The effect of N-fertility source and rate on the number of rating dates that tall fescue visual turfgrass color was ≥ 5.0, ≥ 5.5, ≥ 6.0, and ≥ 6.5 (based on a 1 to 9 scale, with 1=brown, 5=minimally acceptable, and 9=darkest tall fescue) from 6 Nov. 2002 to 8 Oct. 2004.

		6 Nov. 2002 to 10 Oct. 2003				24 Oct. 2003 to 8 Oct. 2004				6 Nov. 2002 to 8 Oct. 2004			
Treatment		≥ 5.0	≥ 5.5	≥ 6.0	≥ 6.5	≥ 5.0	≥ 5.5	≥ 6.0	≥ 6.5	≥ 5.0	≥ 5.5	≥ 6.0	≥ 6.5
		----------- Total of 24 rating dates -----------				*----------- Total of 26 rating dates -----------*				*----------- Total of 50 rating dates -----------*			
ANOVA, RCB design, 13 treatments													
Source[z]	Rate[y]												
Ammonium nitrate	8	24 a[x]	24 a	20 ab	17 a	26 a	26 a	26 a	12 ab	50 a	50 a	46 ab	29 ab
Milorganite	8	24 a	19 ab	13 abc	7 abc	26 a	26 a	24 ab	11 ab	50 a	45 ab	37 bcd	18 abcd
Nutralene	8	24 a	20 ab	19 ab	6 abc	26 a	26 a	24 ab	9 abc	50 a	46 ab	43 abc	15 bcd
Polyon	8	24 a	24 a	23 a	14 ab	26 a	26 a	26 a	20 a	50 a	50 a	49 a	34 a
Ammonium nitrate	6	24 a	20 ab	17 abc	14 ab	26 a	26 a	22 ab	11 ab	50 a	46 ab	39 abc	25 abc
Milorganite	6	24 a	18 abc	12 abc	4 bc	26 a	26 a	22 ab	9 ab	50 a	44 ab	34 bcd	13 bcde
Nutralene	6	24 a	20 ab	13 abc	4 bc	26 a	25 a	22 ab	12 ab	50 a	45 ab	35 bcd	16 bcd
Polyon	6	24 a	24 a	17 abc	5 abc	26 a	26 a	25 ab	10 ab	50 a	50 a	42 abc	15 bcd
Ammonium nitrate	4	24 a	20 ab	15 abc	5 abc	26 a	24 a	20 ab	8 abc	50 a	44 ab	35 bcd	13 bcde
Milorganite	4	19 ab	9 bc	5 cd	2 c	26 a	24 a	16 b	2 bc	45 a	33 b	21 d	4 def
Nutralene	4	24 a	15 abc	8 bcd	2 c	26 a	25 a	22 ab	8 abc	50 a	40 b	30 cd	10 cde
Polyon	4	24 a	18 abc	9 bcd	0 c	26 a	26 a	22 ab	2 bc	50 a	44 ab	31 cd	2 ef
Check	0	9 b	6 c	1 d	0 c	12 b	8 b	3 c	0 c	21 b	14 c	4 e	0 f
ANOVA, 4 × 3 factorial design, 12 treatments													
Source[z]													
Ammonium nitrate		24	22 a	18	15 a	26	26	22	11	50	48 a	40 a	26 a
Milorganite		24	17 a	10	4 b	26	26	22	8	50	43 a	32 a	12 b
Nutralene		24	20 a	11	4 b	26	26	22	8	50	46 a	33 a	12 b
Polyon		24	24 a	17	5 b	26	26	26	10	50	50 a	43 a	15 ab
Rate[y]													
8		24	24 a	20 a	10 a	26	26	25	15 a	50	50 a	45 a	25 a
6		24	21 a	18 a	4 a	26	26	23	10 a	50	47 ab	41 a	14 ab
4		24	18 a	8 b	2 a	26	25	23	5 b	50	43 b	31 b	7 b

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's Exact Test (protected) and Chi-Square Test (protected), P = 0.05 or 0.10. Means followed by the same letter are not significantly different. Means not followed by letters are not significantly different and the treatment effect is not significant.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 17. The effect of N-fertility source and rate on the percent coverage of *Rhizoctonia* brown patch from Aug. to Sept. 2004.

Treatment		6 Aug. 2004	25 Aug. 2004	2 Sept. 2004	Overall
ANOVA, repeated measures of a RCB design, 13 treatments					
Source[z]	Rate[y]				
Ammonium nitrate	8	6.5	6.5	7.0	6.7
Milorganite	8	17.0	3.8	7.3	9.3
Nutralene	8	8.0	3.0	3.0	4.7
Polyon	8	6.3	9.0	11.3	8.8
Ammonium nitrate	6	5.5	0.0	0.3	1.9
Milorganite	6	3.0	6.3	7.3	5.5
Nutralene	6	14.5	0.5	1.0	5.3
Polyon	6	12.5	0.5	0.3	4.4
Ammonium nitrate	4	1.3	4.8	5.5	3.8
Milorganite	4	0.8	2.3	2.8	1.9
Nutralene	4	6.8	3.8	3.3	4.6
Polyon	4	3.3	0.3	0.5	1.3
Check	0	0.0	0.0	0.0	0.0
LSD, $P=0.05$[x]		NS	NS	NS	NS
Repeated measures design effects (P)					
Treatment (T)		0.3104	0.3060	0.3154	0.5621
Date (D)					0.2898
T x D					0.0321
ANOVA, repeated measures of a 4 × 3 factorial design, 12 treatments					
Source[z]					
Ammonium nitrate		4.4	3.8	4.3	4.1
Milorganite		6.9	4.1	5.8	5.6
Nutralene		9.8	2.4	2.4	4.9
Polyon		7.3	3.3	4.0	4.9
LSD, $P=0.05$[x]		NS	NS	NS	NS
Rate[x]					
8		9.4	5.6	7.1	7.4
6		8.9	1.8	2.2	4.3
4		3.0	2.8	3.0	2.9
LSD, $P=0.05$[x]		NS	NS	NS	NS
Factorial repeated measures design effects (P)					
Source (S)		0.6369	0.8829	0.6779	0.9504
Rate (R)		0.1467	0.1372	0.0926	0.3158
S x R		0.4494	0.2902	0.4536	0.7259
Date (D)					0.2898
D x S					0.1445
D x R					0.1796
D x S x R					0.0985

[z] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y] Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Figure 12. The effect of 13 treatments on NO_3^--N concentration in leachate, 9 Oct. 2002 to 29 Sept. 2004.

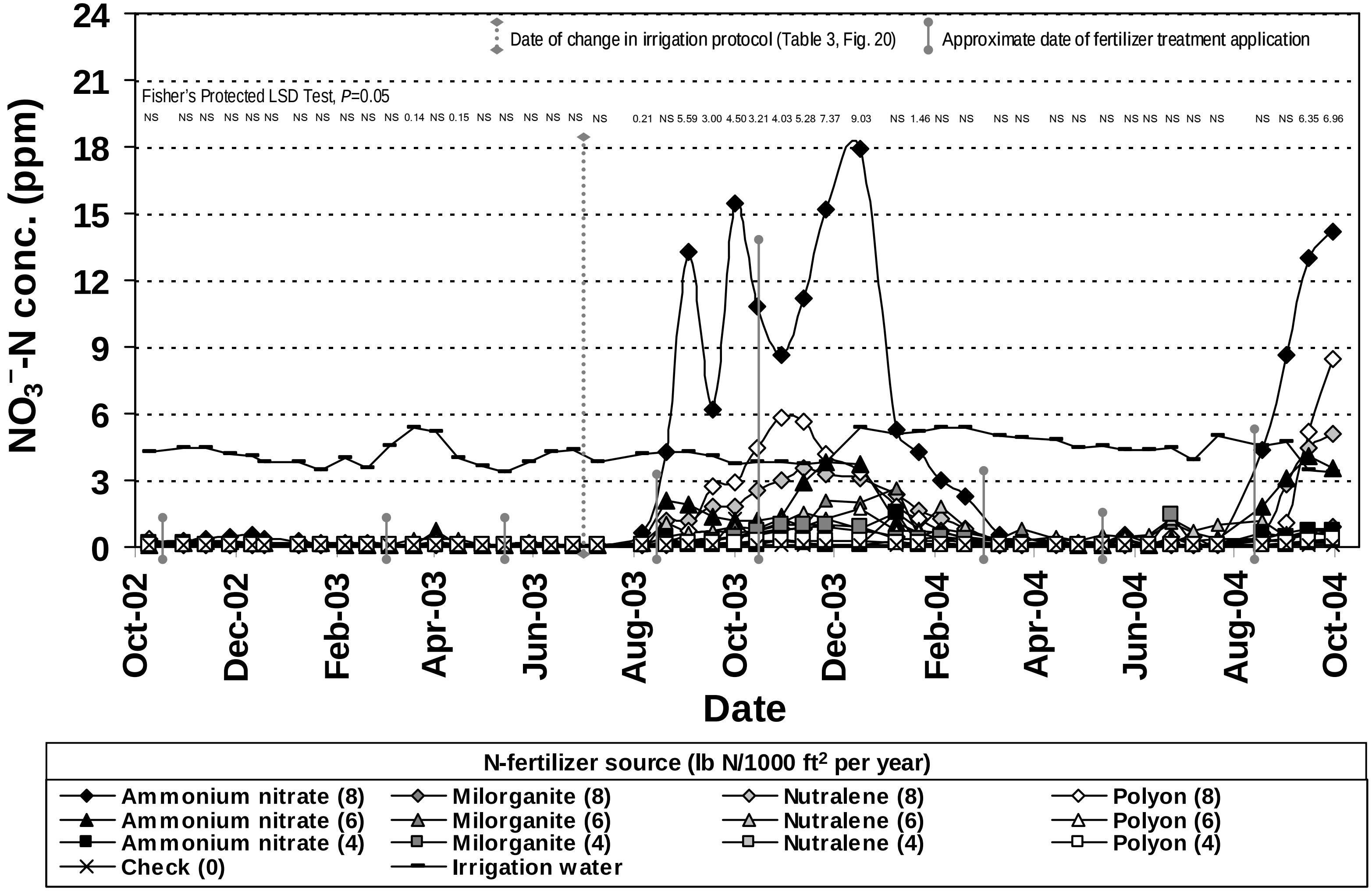


Figure 13. The effect of four N-fertilizer sources on NO_3^--N concentration in leachate, 9 Oct. 2002 to 29 Sept. 2004. Means are the average of three N-fertilizer rates.

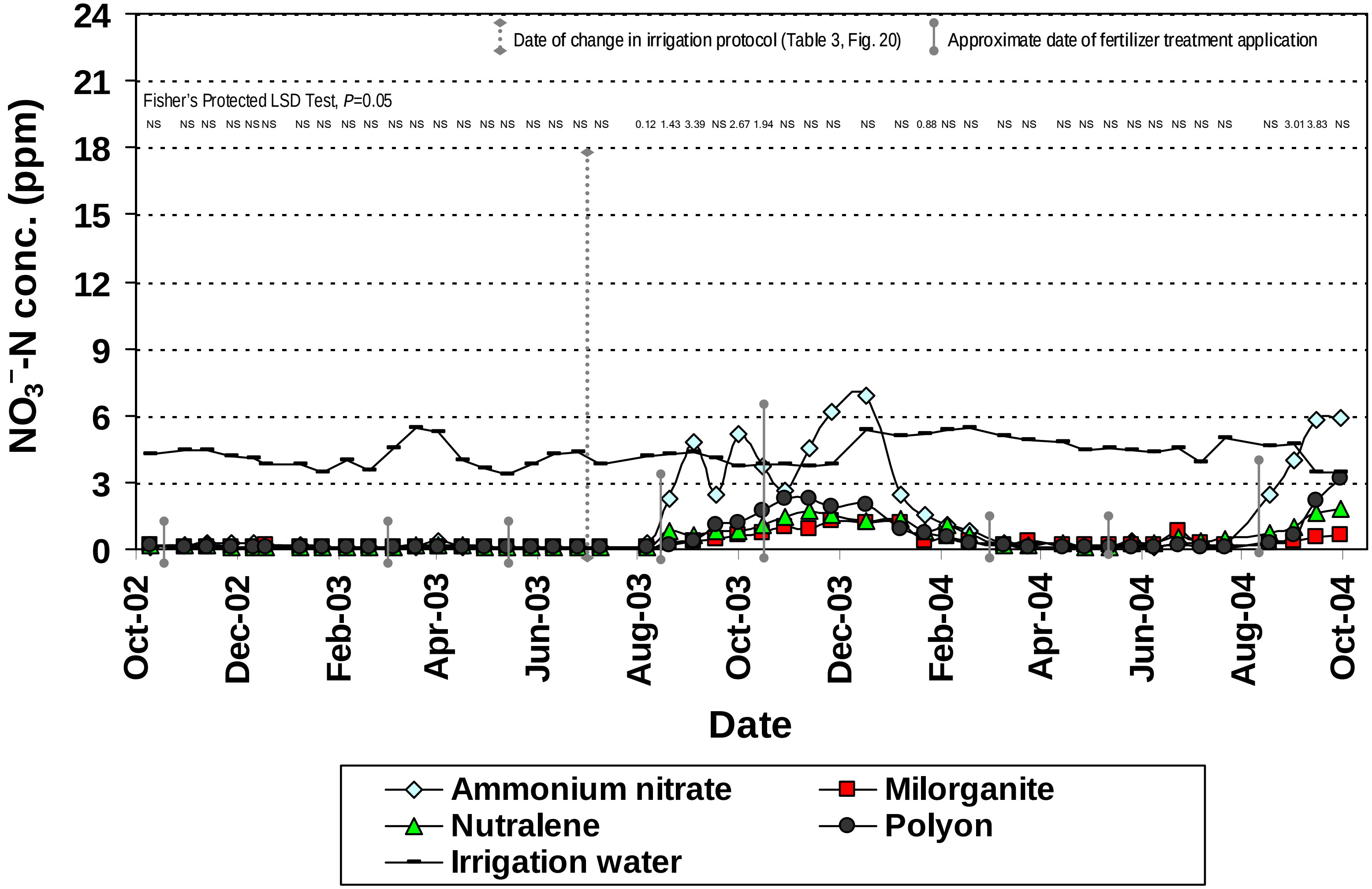


Figure 14. The effect of three N-fertilizer rates on NO_3^--N concentration in leachate, 9 Oct. 2002 to 29 Sept. 2004. Means are the average of four N-fertilizer sources.

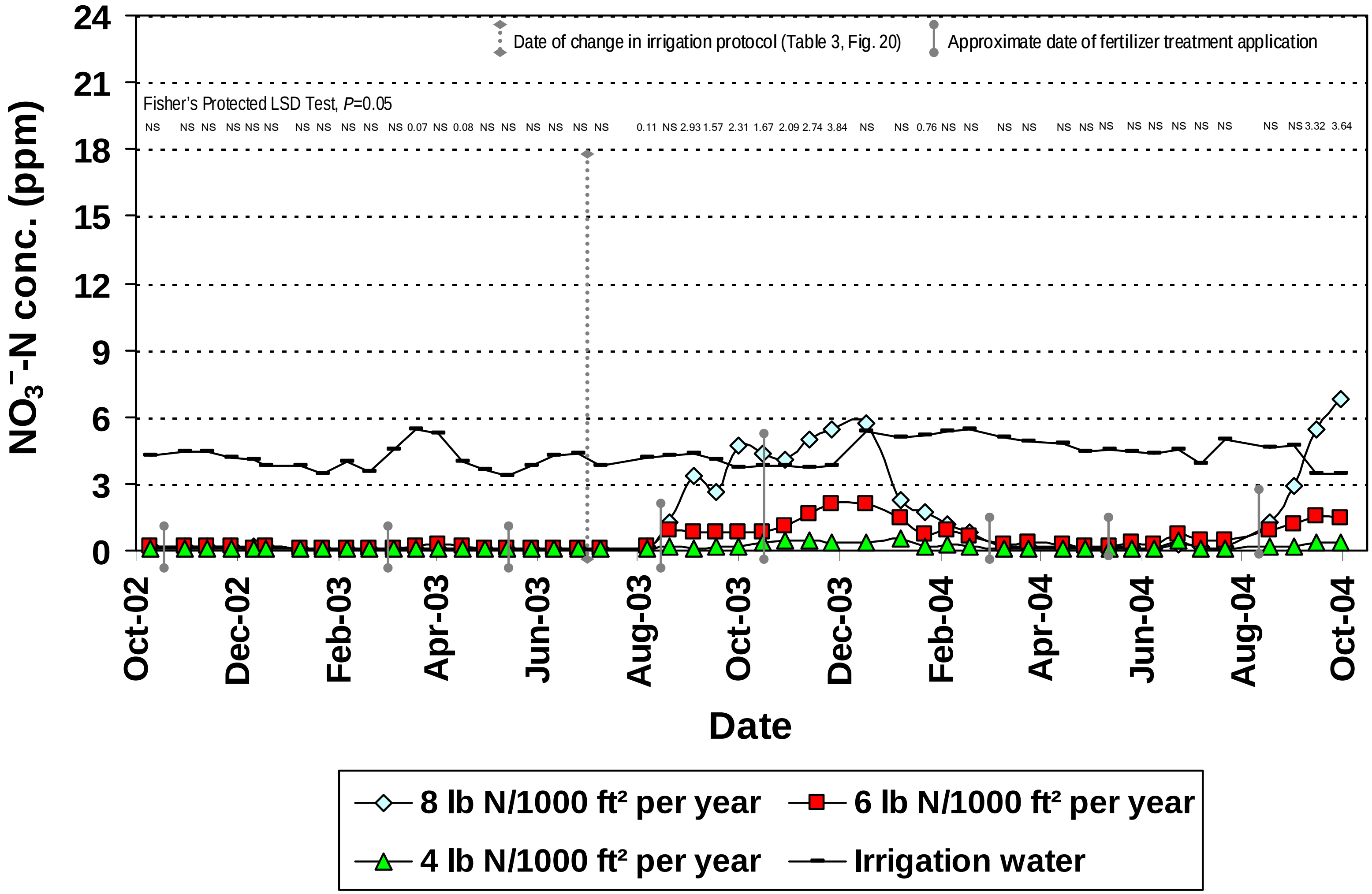


Table 18.1. The effect of N-fertility source and rate on NO_3^--N leached at the 2.5-ft depth from tall fescue from Oct. 2002 to Mar. 2003.

Treatment		9 Oct. 2002	30 Oct. 2002	13 Nov. 2002	27 Nov. 2003	11 Dec. 2003	18 Dec. 2002	8 Jan. 2003	22 Jan. 2003	5 Feb. 2003	19 Feb. 2003	5 Mar. 2003	19 Mar. 2003
		ppm											
ANOVA, RCB design, 13 treatments													
Source[z]	Rate[y]												
Ammonium nitrate	8	0.10	0.27	0.39	0.45	0.51	0.32	0.27	0.12	0.06	0.07	0.06	0.08
Milorganite	8	0.11	0.09	0.11	0.11	0.13	0.14	0.14	0.16	0.20	0.15	0.10	0.10
Nutralene	8	0.18	0.23	0.17	0.07	0.05	0.13	0.05	0.05	0.05	0.09	0.06	0.06
Polyon	8	0.32	0.09	0.08	0.06	0.05	0.09	0.05	0.05	0.05	0.07	0.06	0.05
Ammonium nitrate	6	0.07	0.19	0.24	0.28	0.21	0.17	0.22	0.14	0.09	0.07	0.06	0.13
Milorganite	6	0.23	0.20	0.19	0.19	0.16	0.21	0.18	0.06	0.05	0.07	0.06	0.11
Nutralene	6	0.18	0.20	0.29	0.05	0.05	0.10	0.05	0.05	0.07	0.07	0.05	0.37
Polyon	6	0.13	0.06	0.08	0.08	0.05	0.08	0.07	0.05	0.05	0.07	0.06	0.07
Ammonium nitrate	4	0.10	0.19	0.09	0.05	0.05	0.05	0.05	0.05	0.05	0.07	0.07	0.06
Milorganite	4	0.18	0.05	0.10	0.05	0.08	0.09	0.09	0.05	0.05	0.06	0.05	0.05
Nutralene	4	0.08	0.11	0.09	0.14	0.05	0.05	0.05	0.05	0.07	0.08	0.06	0.06
Polyon	4	0.08	0.07	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.07	0.06	0.05
Check	0	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.07	0.05	0.05
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.14
Randomized complete block design effects (*P*)													
Treatment		0.3772	0.5512	0.5054	0.4686	0.3848	0.5302	0.5409	0.6607	0.6181	0.7052	0.5037	0.0037
ANOVA, 4 × 3 factorial design, 12 treatments													
Source[z]													
Ammonium nitrate		0.09	0.21	0.24	0.26	0.25	0.18	0.18	0.11	0.07	0.07	0.06	0.09
Milorganite		0.18	0.12	0.13	0.12	0.12	0.14	0.13	0.09	0.10	0.09	0.07	0.09
Nutralene		0.15	0.18	0.19	0.08	0.05	0.09	0.05	0.05	0.06	0.08	0.06	0.18
Polyon		0.17	0.07	0.07	0.06	0.05	0.07	0.06	0.05	0.05	0.07	0.06	0.06
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate[y]													
8		0.18	0.16	0.17	0.16	0.17	0.16	0.12	0.10	0.10	0.10	0.07	0.07
6		0.15	0.16	0.20	0.15	0.12	0.14	0.13	0.08	0.06	0.07	0.06	0.17
4		0.11	0.10	0.08	0.07	0.06	0.06	0.06	0.05	0.05	0.07	0.06	0.05
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.07
Factorial design effects (*P*)													
Source (S)		0.5853	0.1443	0.2290	0.1915	0.1243	0.2481	0.1634	0.3519	0.6095	0.8055	0.6426	0.1109
Rate (R)		0.5702	0.6038	0.3316	0.5886	0.4557	0.2269	0.5048	0.5228	0.6695	0.4125	0.4567	0.0088
S x R		0.3114	0.8914	0.8120	0.6226	0.5998	0.8717	0.8494	0.7850	0.4581	0.5752	0.4624	0.0505

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 18.2. The effect of N-fertility source and rate on NO_3^--N leached at the 2.5-ft depth from tall fescue from Apr. to Sept. 2003.

Treatment		2 Apr. 2003	16 Apr. 2003	30 Apr. 2003	14 May 2003	28 May 2003	11 June 2003	25 June 2003	9 July 2003	6 Aug. 2003	20 Aug. 2003	3 Sept. 2003	17 Sept. 2003
		ppm											
ANOVA, RCB design, 13 treatments													
Source[z]	Rate[y]												
Ammonium nitrate	8	0.16	0.08	0.07	0.09	0.15	0.07	0.08	0.09	0.63	4.31	13.31	6.17
Milorganite	8	0.06	0.06	0.07	0.07	0.07	0.06	0.06	0.06	0.07	0.12	0.24	0.39
Nutralene	8	0.08	0.08	0.07	0.07	0.08	0.06	0.06	0.06	0.09	1.17	1.17	1.78
Polyon	8	0.05	0.05	0.07	0.12	0.21	0.10	0.08	0.08	0.10	0.23	0.73	2.72
Ammonium nitrate	6	0.72	0.06	0.05	0.06	0.08	0.06	0.06	0.06	0.16	2.08	1.91	1.35
Milorganite	6	0.05	0.13	0.05	0.05	0.05	0.05	0.05	0.05	0.11	0.41	0.64	0.69
Nutralene	6	0.35	0.33	0.05	0.05	0.05	0.05	0.06	0.05	0.22	1.07	0.60	0.75
Polyon	6	0.10	0.14	0.11	0.08	0.09	0.08	0.08	0.08	0.13	0.18	0.30	0.39
Ammonium nitrate	4	0.05	0.06	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.50	0.07	0.07
Milorganite	4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.18	0.15	0.29
Nutralene	4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.07	0.10
Polyon	4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.14	0.19
Check	0	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.08
LSD, $P=0.05$[x]		NS	0.15	NS	NS	NS	NS	NS	NS	0.21	NS	5.59	3.00
Randomized complete block design effects (P)													
Treatment		0.5231	0.0298	0.2277	0.5218	0.4520	0.5316	0.4358	0.3008	0.0006	0.0614	0.0089	0.0238
ANOVA, 4 × 3 factorial design, 12 treatments													
Source[z]													
Ammonium nitrate		0.35	0.07	0.06	0.06	0.09	0.06	0.06	0.07	0.27	2.28	4.78	2.41
Milorganite		0.05	0.08	0.06	0.06	0.06	0.05	0.05	0.06	0.08	0.24	0.34	0.46
Nutralene		0.18	0.17	0.06	0.06	0.06	0.05	0.06	0.05	0.13	0.79	0.61	0.86
Polyon		0.07	0.08	0.08	0.08	0.12	0.08	0.07	0.07	0.09	0.17	0.39	1.10
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	0.12	1.43	3.39	NS
Rate[y]													
8		0.08	0.07	0.07	0.09	0.13	0.07	0.07	0.07	0.20	1.27	3.38	2.59
6		0.30	0.16	0.06	0.06	0.07	0.06	0.06	0.06	0.15	0.93	0.86	0.79
4		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.20	0.12	0.17
LSD, $P=0.05$[x]		NS	0.08	NS	NS	NS	NS	NS	NS	0.11	NS	2.93	1.57
Factorial design effects (P)													
Source (S)		0.3974	0.2838	0.3271	0.4618	0.5027	0.3152	0.2284	0.2521	0.0087	0.0132	0.0167	0.1623
Rate (R)		0.2590	0.0170	0.1701	0.0804	0.0707	0.1558	0.1661	0.0913	0.0145	0.2014	0.0492	0.0056
S x R		0.7410	0.2147	0.3307	0.9577	0.8675	0.9482	0.8887	0.7851	0.0045	0.4484	0.0448	0.1958

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 18.3. The effect of N-fertility source and rate on NO_3^--N leached at the 2.5-ft depth from tall fescue from Oct. 2003 to Mar. 2004.

Treatment		1 Oct. 2003	15 Oct. 2003	29 Oct. 2003	12 Nov. 2003	26 Nov. 2003	17 Dec. 2003	7 Jan. 2004	21 Jan. 2004	4 Feb. 2004	18 Feb. 2004	10 Mar. 2004	24 Mar. 2004
		ppm											
ANOVA, RCB design, 13 treatments													
Source[z]	Rate[y]												
Ammonium nitrate	8	15.47	10.80	8.62	11.14	15.17	17.95	5.29	4.28	3.04	2.25	0.54	0.32
Milorganite	8	0.49	0.65	0.78	0.80	0.87	0.71	0.44	0.30	0.25	0.16	0.12	0.10
Nutralene	8	1.84	2.55	3.00	3.54	3.30	3.11	2.40	1.61	1.24	0.78	0.23	0.32
Polyon	8	2.88	4.46	5.84	5.60	4.16	3.39	1.84	1.28	0.77	0.33	0.09	0.11
Ammonium nitrate	6	1.20	1.22	1.37	2.88	3.85	3.72	1.07	0.65	0.38	0.34	0.29	0.36
Milorganite	6	0.88	0.80	1.28	0.94	2.07	2.00	2.66	0.48	0.86	0.62	0.35	0.78
Nutralene	6	0.66	0.72	1.11	1.56	1.27	0.84	1.51	0.78	1.78	0.95	0.13	0.26
Polyon	6	0.43	0.57	0.74	0.87	1.23	1.76	0.70	0.76	0.64	0.48	0.30	0.16
Ammonium nitrate	4	0.06	0.07	0.34	0.20	0.09	0.05	1.58	0.05	0.15	0.05	0.05	0.05
Milorganite	4	0.43	0.76	0.97	1.04	0.99	0.91	0.39	0.37	0.46	0.39	0.09	0.08
Nutralene	4	0.12	0.14	0.27	0.15	0.13	0.09	0.26	0.06	0.16	0.10	0.05	0.06
Polyon	4	0.21	0.23	0.25	0.24	0.23	0.28	0.19	0.16	0.13	0.10	0.06	0.10
Check	0	1.25	0.08	0.08	0.09	0.07	0.05	0.05	0.05	0.07	0.05	0.05	0.05
LSD, $P=0.05$[x]		4.50	3.21	4.03	5.28	7.37	9.03	NS	1.46	NS	NS	NS	NS
Randomized complete block design effects (P)													
Treatment		<0.0001	<0.0001	0.0112	0.0126	0.0364	0.0506	0.1012	0.0004	0.1337	0.1132	0.3551	0.6670
ANOVA, 4 × 3 factorial design, 12 treatments													
Source[z]													
Ammonium nitrate		5.14	3.75	2.63	4.56	6.12	6.89	2.49	1.56	1.11	0.83	0.29	0.26
Milorganite		0.60	0.74	1.01	0.92	1.31	1.21	1.16	0.37	0.52	0.39	0.18	0.32
Nutralene		0.85	1.09	1.42	1.73	1.54	1.30	1.40	0.81	1.13	0.64	0.14	0.22
Polyon		1.17	1.75	2.27	2.24	1.88	1.95	0.91	0.73	0.51	0.30	0.15	0.12
LSD, $P=0.05$[x]		2.67	1.94	NS	NS	NS	NS	NS	0.88	NS	NS	NS	NS
Rate[y]													
8		4.67	4.32	4.05	4.98	5.39	5.68	2.30	1.71	1.21	0.79	0.22	0.20
6		0.79	0.83	1.12	1.60	2.10	2.08	1.48	0.68	0.91	0.60	0.26	0.39
4		0.22	0.33	0.48	0.44	0.40	0.38	0.56	0.17	0.23	0.17	0.06	0.08
LSD, $P=0.05$[x]		2.31	1.67	2.09	2.74	3.84	NS	NS	0.76	NS	NS	NS	NS
Factorial design effects (P)													
Source (S)		0.0017	0.0068	0.1886	0.0921	0.0641	0.0662	0.2058	0.0371	0.4268	0.3701	0.5621	0.7731
Rate (R)		0.0004	<0.0001	0.0012	0.0056	0.0343	0.0595	0.0924	0.0006	0.1168	0.1378	0.1285	0.2515
S x R		0.0007	0.0020	0.0917	0.1493	0.1720	0.1665	0.2053	0.0115	0.1574	0.1070	0.4876	0.6856

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 18.4. The effect of N-fertility source and rate on NO_3^--N leached at the 2.5-ft depth from tall fescue from Apr. to Sept. 2004.

Treatment		14 Apr. 2004	28 Apr. 2004	12 May 2004	26 May 2004	9 June 2004	23 June 2004	7 July 2004	21 July 2004	18 Aug. 2004	1 Sept. 2004	15 Sept. 2004	29 Sept. 2004
		ppm											
ANOVA, RCB design, 13 treatments													
Source[z]	Rate[y]												
Ammonium nitrate	8	0.28	0.17	0.14	0.52	0.15	0.21	0.50	0.18	4.34	8.66	13.04	14.19
Milorganite	8	0.19	0.06	0.07	0.05	0.06	0.06	0.06	0.08	0.24	0.39	0.62	0.90
Nutralene	8	0.18	0.09	0.06	0.27	0.10	0.12	0.13	0.14	0.62	2.78	4.43	5.11
Polyon	8	0.10	0.08	0.08	0.08	0.07	0.50	0.10	0.16	0.39	1.10	5.20	8.48
Ammonium nitrate	6	0.27	0.10	0.11	0.37	0.11	0.35	0.24	0.32	1.86	3.12	4.08	3.59
Milorganite	6	0.32	0.31	0.52	0.46	0.41	1.07	0.65	0.40	0.39	0.61	0.80	0.85
Nutralene	6	0.42	0.23	0.16	0.47	0.53	1.28	0.69	0.99	1.21	0.45	0.68	0.56
Polyon	6	0.22	0.14	0.08	0.07	0.06	0.09	0.08	0.10	0.26	0.37	0.59	0.71
Ammonium nitrate	4	0.07	0.07	0.06	0.06	0.07	0.06	0.07	0.06	0.65	0.41	0.71	0.75
Milorganite	4	0.11	0.06	0.05	0.05	0.06	1.47	0.11	0.07	0.06	0.06	0.15	0.28
Nutralene	4	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.10	0.16	0.14
Polyon	4	0.08	0.10	0.06	0.05	0.06	0.05	0.05	0.05	0.09	0.19	0.31	0.35
Check	0	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.06	0.06	0.05
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	6.35	6.96
Randomized complete block design effects (P)													
Treatment		0.9126	0.7283	0.5523	0.5213	0.7151	0.6453	0.4091	0.7524	0.2160	0.1083	0.0190	0.0103
ANOVA, 4 × 3 factorial design, 12 treatments													
Source[z]													
Ammonium nitrate		0.21	0.11	0.10	0.32	0.11	0.23	0.27	0.17	2.41	3.97	5.76	5.92
Milorganite		0.21	0.14	0.21	0.19	0.17	0.86	0.27	0.18	0.23	0.35	0.52	0.67
Nutralene		0.24	0.13	0.10	0.28	0.26	0.53	0.33	0.45	0.69	1.04	1.65	1.80
Polyon		0.13	0.11	0.07	0.07	0.06	0.21	0.08	0.11	0.26	0.59	2.19	3.18
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	NS	3.01	3.83	NS
Rate[y]													
8		0.18	0.10	0.08	0.21	0.09	0.24	0.18	0.14	1.24	2.88	5.41	6.81
6		0.31	0.19	0.22	0.34	0.28	0.68	0.43	0.47	0.93	1.14	1.53	1.42
4		0.08	0.07	0.06	0.05	0.06	0.49	0.07	0.06	0.16	0.18	0.32	0.37
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	3.32	3.64
Factorial design effects (P)													
Source (S)		0.9083	0.9748	0.6236	0.4455	0.7761	0.5186	0.6370	0.7875	0.0788	0.0465	0.0297	0.0602
Rate (R)		0.2375	0.2181	0.2967	0.1903	0.2592	0.5568	0.2013	0.2687	0.3398	0.0899	0.0083	0.0021
S x R		0.9872	0.7215	0.5336	0.7503	0.7629	0.5045	0.5104	0.8567	0.6361	0.5081	0.3648	0.3275

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Figure 15. The effect of 13 treatments on NH_4^+-N concentration in leachate, 22 Jan. 2003 to 29 Sept. 2004.

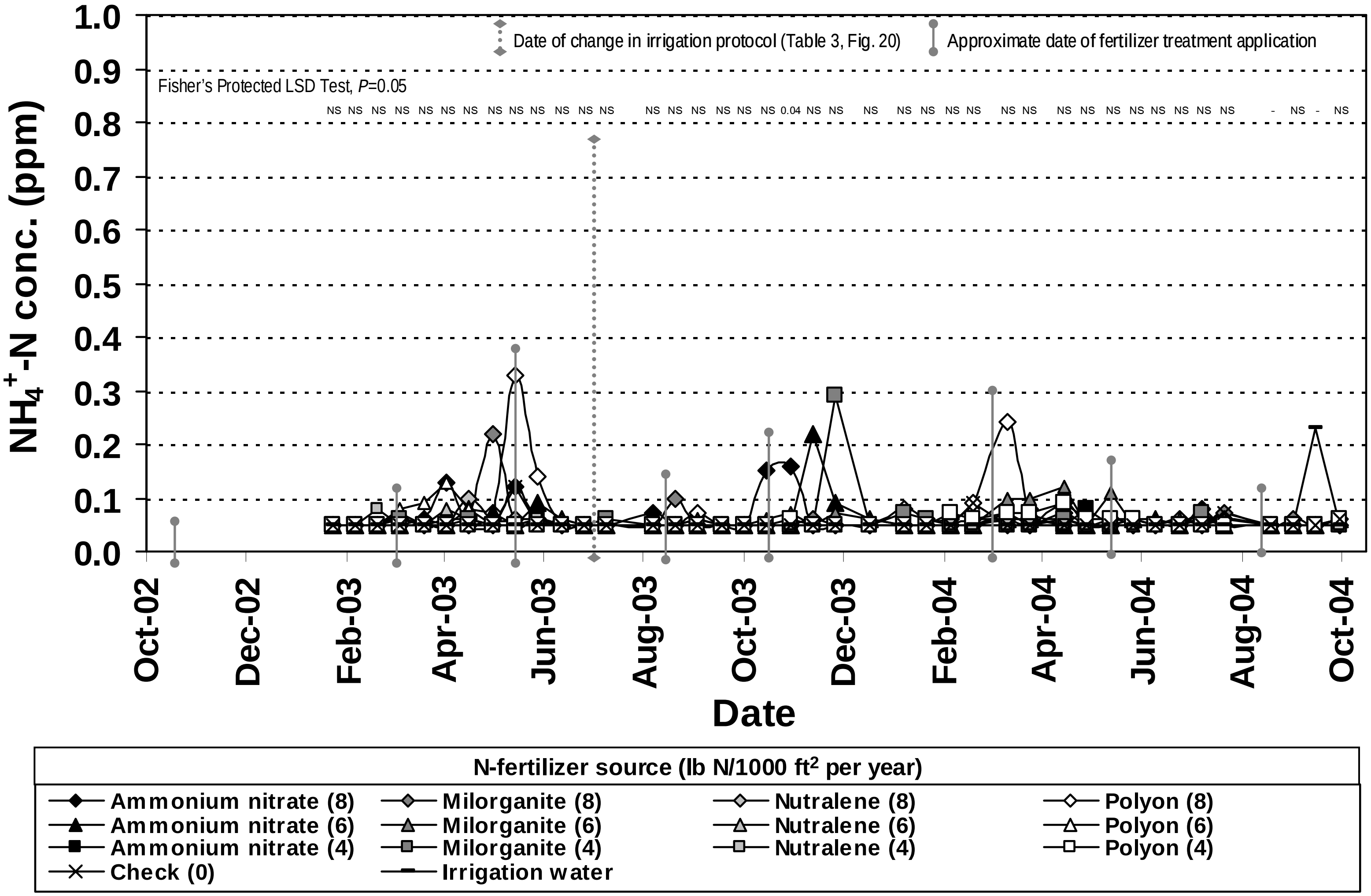


Figure 16. The effect of four N-fertilizer sources on NH_4^+-N concentration in leachate, 22 Jan. 2003 to 29 Sept. 2004. Means are the average of three N-fertilizer rates.

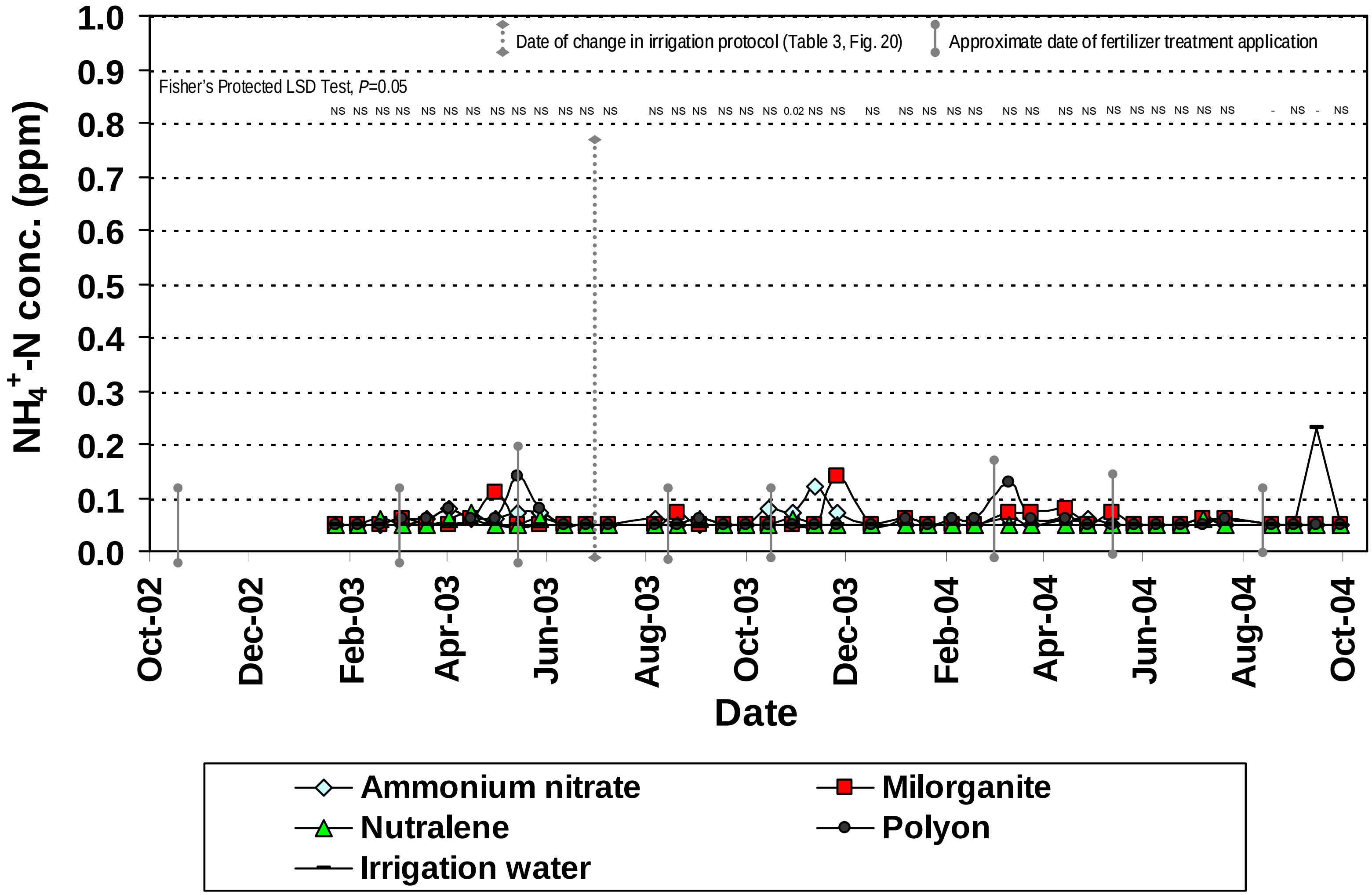


Figure 17. The effect of three N-fertilizer rates on NH_4^+-N concentration in leachate, 22 Jan. 2003 to 29 Sept. 2004. Means are the average of four N-fertilizer sources.

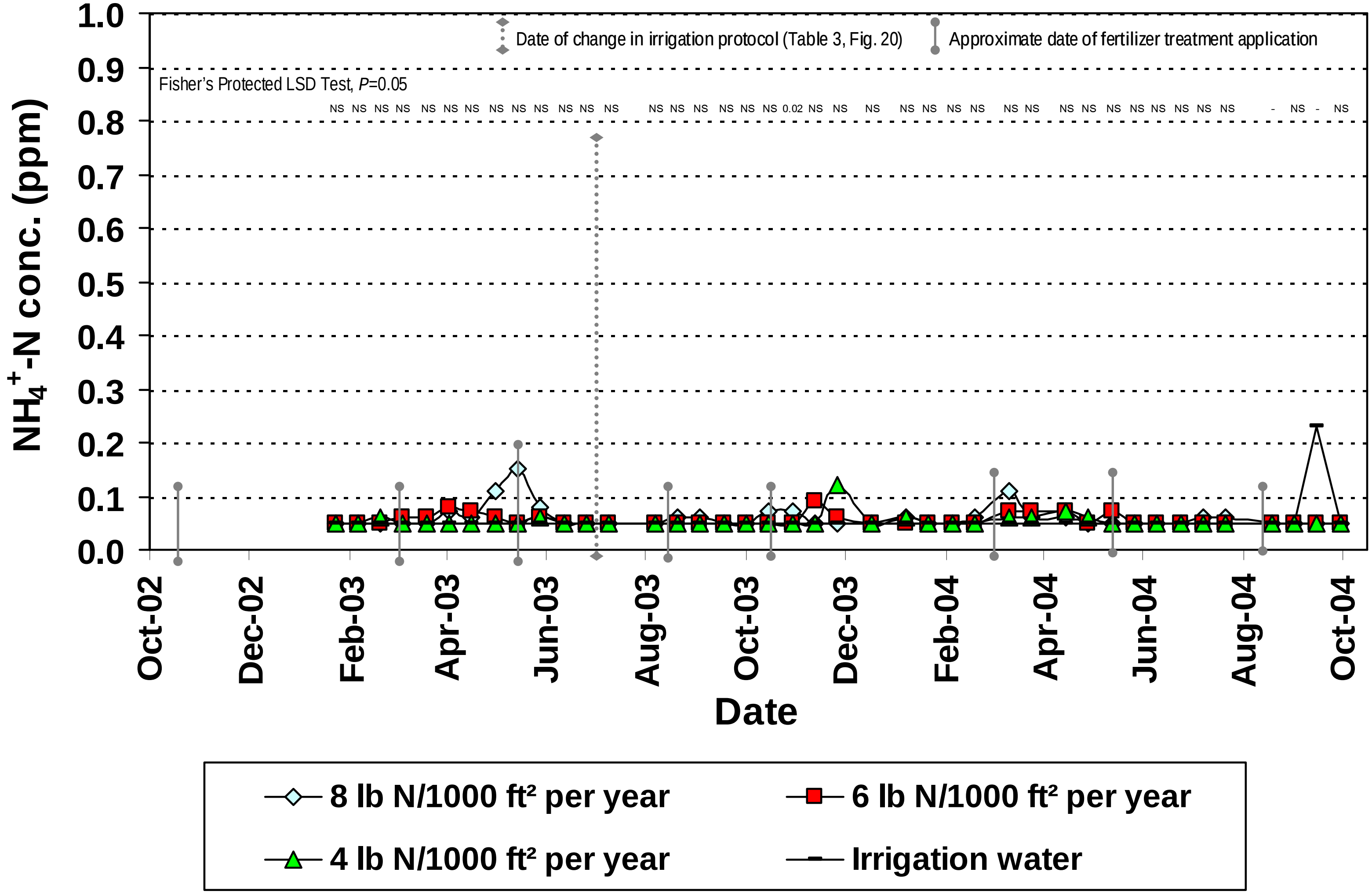


Table 19.1. The effect of N-fertility source and rate on NH_4^+-N leached at the 2.5-ft depth from tall fescue from Jan. to June 2003.

Treatment		22 Jan. 2003	5 Feb. 2003	19 Feb. 2003	5 Mar. 2003	19 Mar. 2003	2 Apr. 2003	16 Apr. 2003	30 Apr. 2003	14 May 2003	28 May 2003	11 June 2003	25 June 2003
		ppm											
ANOVA, RCB design, 13 treatments													
Source[z]	Rate[y]												
Ammonium nitrate	8	0.05	0.05	0.05	0.05	0.06	0.13	0.05	0.05	0.12	0.06	0.05	0.05
Milorganite	8	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.22	0.05	0.06	0.05	0.05
Nutralene	8	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.06	0.06	0.06	0.05	0.05
Polyon	8	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.07	0.33	0.14	0.05	0.05
Ammonium nitrate	6	0.05	0.05	0.05	0.05	0.06	0.05	0.08	0.07	0.05	0.09	0.06	0.05
Milorganite	6	0.05	0.05	0.05	0.07	0.05	0.06	0.06	0.05	0.05	0.05	0.05	0.05
Nutralene	6	0.05	0.05	0.05	0.05	0.05	0.08	0.06	0.05	0.05	0.05	0.06	0.05
Polyon	6	0.05	0.05	0.05	0.08	0.09	0.13	0.08	0.05	0.05	0.06	0.05	0.05
Ammonium nitrate	4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05
Milorganite	4	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.05
Nutralene	4	0.05	0.05	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05
Polyon	4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Check	0	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.12	0.05	0.05	0.05
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Randomized complete block design effects (P)													
Treatment		.	0.2682	0.2737	0.5240	0.5805	0.1952	0.6542	0.6108	0.5558	0.5478	0.5478	0.5304
ANOVA, 4 × 3 factorial design, 12 treatments													
Source[z]													
Ammonium nitrate		0.05	0.05	0.05	0.05	0.06	0.08	0.06	0.06	0.07	0.07	0.05	0.05
Milorganite		0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.11	0.05	0.05	0.05	0.05
Nutralene		0.05	0.05	0.06	0.05	0.05	0.06	0.07	0.05	0.05	0.06	0.05	0.05
Polyon		0.05	0.05	0.05	0.06	0.06	0.08	0.06	0.06	0.14	0.08	0.05	0.05
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate[y]													
8		0.05	0.05	0.05	0.05	0.05	0.07	0.06	0.11	0.15	0.08	0.05	0.05
6		0.05	0.05	0.05	0.06	0.06	0.08	0.07	0.06	0.05	0.06	0.05	0.05
4		0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Factorial design effects (P)													
Source (S)		.	0.0418	0.2228	0.2736	0.5054	0.4263	0.8029	0.5607	0.5515	0.5861	0.5818	0.5572
Rate (R)		.	0.4666	0.2064	0.3719	0.4679	0.4554	0.4860	0.4092	0.2307	0.4697	0.1803	0.5262
S x R		.	0.5421	0.3100	0.7287	0.5107	0.1094	0.4451	0.5918	0.6619	0.4754	0.6986	0.3677

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 19.2. The effect of N-fertility source and rate on NH_4^+-N leached at the 2.5-ft depth from tall fescue from July 2003 to Jan. 2004.

Treatment		9 July 2003	6 Aug. 2003	20 Aug. 2003	3 Sept. 2003	17 Sept. 2003	1 Oct. 2003	15 Oct. 2003	29 Oct. 2003	12 Nov. 2003	26 Nov. 2003	17 Dec. 2003	7 Jan. 2004
		ppm											
ANOVA, RCB design, 13 treatments													
Source[z]	Rate[y]												
Ammonium nitrate	8	0.05	0.07	0.05	0.05	0.05	0.05	0.15	0.16	0.05	0.05	0.05	0.05
Milorganite	8	0.05	0.05	0.10	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.05
Nutralene	8	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Polyon	8	0.05	0.05	0.05	0.07	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08
Ammonium nitrate	6	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.22	0.09	0.06	0.05
Milorganite	6	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.07	0.06	0.05
Nutralene	6	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.07	0.05	0.05	0.05	0.05
Polyon	6	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Ammonium nitrate	4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Milorganite	4	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.29	0.05	0.07
Nutralene	4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Polyon	4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.05
Check	0	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	0.04	NS	NS	NS	NS
Randomized complete block design effects (*P*)													
Treatment		0.6947	0.2467	0.5864	0.6220	.	.	0.1485	0.0214	0.5842	0.6001	0.6653	0.6844
ANOVA, 4 × 3 factorial design, 12 treatments													
Source[z]													
Ammonium nitrate		0.05	0.06	0.05	0.05	0.05	0.05	0.08	0.07	0.12	0.07	0.05	0.05
Milorganite		0.05	0.05	0.07	0.05	0.05	0.05	0.05	0.05	0.05	0.14	0.05	0.06
Nutralene		0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.05
Polyon		0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	0.02	NS	NS	NS	NS
Rate[y]													
8		0.05	0.05	0.06	0.06	0.05	0.05	0.07	0.07	0.05	0.05	0.05	0.06
6		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.09	0.06	0.05	0.05
4		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.12	0.05	0.06
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	0.02	NS	NS	NS	NS
Factorial design effects (*P*)													
Source (S)		0.6557	0.2793	0.5392	0.7784	.	.	0.1908	0.0294	0.4872	0.4968	0.5918	0.6776
Rate (R)		0.6643	0.1842	0.4811	0.4839	.	.	0.1630	0.0275	0.5028	0.5214	0.2649	0.7259
S x R		0.5425	0.2448	0.5272	0.4657	.	.	0.1569	0.0078	0.6177	0.5517	0.8064	0.4595

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 19.3. The effect of N-fertility source and rate on NH_4^+-N leached at the 2.5-ft depth from tall fescue from Jan. to July 2004.

Treatment		21 Jan. 2004	4 Feb. 2004	18 Feb. 2004	10 Mar. 2004	24 Mar. 2004	14 Apr. 2004	28 Apr. 2004	12 May 2004	26 May 2004	9 June 2004	23 June 2004	7 July 2004
		ppm											
ANOVA, RCB design, 13 treatments													
Source[z]	Rate[y]												
Ammonium nitrate	8	0.05	0.05	0.06	0.06	0.05	0.09	0.05	0.05	0.05	0.05	0.05	0.08
Milorganite	8	0.05	0.05	0.05	0.05	0.05	0.07	0.05	0.06	0.05	0.05	0.05	0.05
Nutralene	8	0.05	0.05	0.05	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.06
Polyon	8	0.06	0.06	0.09	0.24	0.08	0.06	0.05	0.05	0.05	0.05	0.06	0.05
Ammonium nitrate	6	0.05	0.05	0.05	0.06	0.06	0.05	0.05	0.05	0.06	0.06	0.05	0.06
Milorganite	6	0.05	0.05	0.05	0.10	0.10	0.12	0.05	0.11	0.05	0.05	0.05	0.05
Nutralene	6	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05
Polyon	6	0.05	0.05	0.05	0.07	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Ammonium nitrate	4	0.05	0.05	0.05	0.05	0.05	0.05	0.08	0.05	0.06	0.05	0.05	0.05
Milorganite	4	0.06	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.05	0.05	0.07
Nutralene	4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Polyon	4	0.05	0.07	0.06	0.07	0.07	0.09	0.06	0.06	0.06	0.05	0.05	0.05
Check	0	0.05	0.05	0.09	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Randomized complete block design effects (*P*)													
Treatment		0.6940	0.5577	0.6973	0.6617	0.6305	0.6665	0.3617	0.6184	0.2217	0.5016	0.6226	0.4080
ANOVA, 4 × 3 factorial design, 12 treatments													
Source[z]													
Ammonium nitrate		0.05	0.05	0.05	0.06	0.05	0.06	0.06	0.05	0.05	0.05	0.05	0.06
Milorganite		0.05	0.05	0.05	0.07	0.07	0.08	0.05	0.07	0.05	0.05	0.05	0.06
Nutralene		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06
Polyon		0.05	0.06	0.06	0.13	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate[y]													
8		0.05	0.05	0.06	0.11	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.06
6		0.05	0.05	0.05	0.07	0.07	0.07	0.05	0.07	0.05	0.05	0.05	0.05
4		0.05	0.05	0.05	0.06	0.06	0.07	0.06	0.05	0.05	0.05	0.05	0.05
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Factorial design effects (*P*)													
Source (S)		0.8021	0.4681	0.4263	0.4381	0.6524	0.5529	0.4496	0.4525	0.4548	0.2117	0.4000	0.3852
Rate (R)		0.5893	0.5344	0.4734	0.6754	0.6965	0.9929	0.2075	0.5480	0.1008	0.6345	0.7802	0.3203
S x R		0.4846	0.5016	0.6487	0.6090	0.4167	0.4586	0.3309	0.5694	0.4102	0.6979	0.5505	0.3261

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 19.4. The effect of N-fertility source and rate on NH_4^+-N leached at the 2.5-ft depth from tall fescue from July to Sept. 2004.

Treatment		21 July 2004	18 Aug. 2004	1 Sept. 2004	15 Sept. 2004	29 Sept. 2004
		ppm				
		ANOVA, RCB design, 13 treatments				
Source[z]	Rate[y]					
Ammonium nitrate	8	0.05	0.05	0.05	0.05	0.05
Milorganite	8	0.07	0.05	0.06	0.05	0.06
Nutralene	8	0.05	0.05	0.05	0.05	0.05
Polyon	8	0.06	0.05	0.05	0.05	0.05
Ammonium nitrate	6	0.05	0.05	0.05	0.05	0.06
Milorganite	6	0.05	0.05	0.05	0.05	0.05
Nutralene	6	0.05	0.05	0.05	0.05	0.06
Polyon	6	0.06	0.05	0.05	0.05	0.05
Ammonium nitrate	4	0.05	0.05	0.05	0.05	0.05
Milorganite	4	0.05	0.05	0.05	0.05	0.05
Nutralene	4	0.05	0.05	0.05	0.05	0.05
Polyon	4	0.05	0.05	0.05	0.05	0.06
Check	0	0.07	0.05	0.05	0.05	0.06
LSD, $P=0.05$[x]		NS	.	NS	.	NS
Randomized complete block design effects (*P*)						
Treatment		0.1398	.	0.1467	.	0.8121
		ANOVA, 4 × 3 factorial design, 12 treatments				
Source[z]						
Ammonium nitrate		0.05	0.05	0.05	0.05	0.05
Milorganite		0.06	0.05	0.05	0.05	0.05
Nutralene		0.05	0.05	0.05	0.05	0.05
Polyon		0.06	0.05	0.05	0.05	0.05
LSD, $P=0.05$[x]		NS	.	NS	.	NS
Rate[y]						
8		0.06	0.05	0.05	0.05	0.05
6		0.05	0.05	0.05	0.05	0.05
4		0.05	0.05	0.05	0.05	0.05
LSD, $P=0.05$[x]		NS	.	NS	.	NS
Factorial design effects (*P*)						
Source (S)		0.2428	.	0.4552	.	0.9721
Rate (R)		0.1420	.	0.4098	.	0.9759
S x R		0.5228	.	0.0915	.	0.3556

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 20. Analyses of NO_3^--N and NH_4^+-N concentrations of irrigation water[z] from 9 Oct. 2002 to 29 Sept. 2004.

Date	NO_3^--N	NH_4^+-N
	ppm	
9 Oct. 2002	4.26	<0.05
30 Oct. 2002	4.42	<0.05
13 Nov. 2002	4.48	<0.05
27 Nov. 2002	4.20	<0.05
11 Dec. 2002	4.12	<0.05
18 Dec. 2002	3.84	<0.05
8 Jan. 2003	3.84	<0.05
22 Jan. 2003	3.46	<0.05
5 Feb. 2003	3.97	<0.05
19 Feb. 2003	3.51	<0.05
5 Mar. 2003	4.56	<0.05
19 Mar. 2003	5.40	<0.05
2 Apr. 2003	5.21	<0.05
16 Apr. 2003	4.02	<0.05
30 Apr. 2003	3.61	<0.05
14 May 2003	3.37	<0.05
28 May 2003	3.82	<0.05
11 June 2003	4.30	<0.05
25 June 2003	4.37	<0.05
9 July 2003	3.79	<0.05
6 Aug. 2003	4.16	<0.05
20 Aug. 2003	4.24	<0.05
3 Sept. 2003	4.31	<0.05
17 Sept. 2003	4.09	<0.05
1 Oct. 2003	3.74	<0.05
15 Oct. 2003	3.84	<0.05
29 Oct. 2003	3.84	<0.05
12 Nov. 2003	3.72	<0.05
26 Nov. 2003	3.79	<0.05
17 Dec. 2003	5.36	<0.05
7 Jan. 2004	5.07	<0.05
21 Jan. 2004	5.19	<0.05
4 Feb. 2004	5.35	<0.05
4 Feb. 2004	5.35	<0.05
18 Feb. 2004	5.39	<0.05
10 Mar. 2004	5.03	<0.05
24 Mar. 2004	4.92	<0.05
14 Apr. 2004	4.82	<0.05
28 Apr. 2004	4.41	<0.05
12 May 2004	4.52	<0.05
26 May 2004	4.40	<0.05
9 June 2004	4.37	<0.05
23 June 2004	4.49	<0.05
7 July 2004	3.90	<0.05
21 July 2004	4.98	<0.05
18 Aug. 2004	4.58	<0.05
1 Sept. 2004	4.73	<0.05
15 Sept. 2004	3.46	0.23
29 Sept. 2004	3.40	<0.05
Mean	4.31	<0.05
Standard error	0.08	0.004

[z]Analyses conducted according to relevant DANR analytical methodologies.

Figure 18. Soil NO_3^--N concentration (ppm, dry-soil basis) at two soil depth zones for each plot sampled on 20 Dec. 2002.

N→

70 ft

7 ft

5 ft

30 ft

1 **0.614** 0.843	2 **0.612** 0.677	3 **0.699** 0.687	4	5 **0.686** 0.767	6 **0.691** 0.687	7 **0.684** 0.833	8 **0.626** 0.684	9	10 **0.613** 0.840
11 **0.613** 0.988	12 **0.692** 0.615	13 **0.703** 0.688	14 **0.615** 0.757	15 **0.690** 0.691	16 **0.694** 0.693	17	18 **0.624** 0.612	19 **0.698** 0.772	20 **0.616** 0.608
21 **0.605** 0.607	22	23 **0.617** 0.687	24 **0.786** 0.610	25 **0.616** 0.675	26 **0.608** 0.692	27 **0.615** 0.604	28 **0.691** 0.692	29 **0.687** 0.620	30 **0.617** 0.688
31 **0.763** 0.599	32 **0.613** 0.762	33 **0.692** 0.915	34	35 **0.608** 0.607	36 **0.611** 0.694	37 **0.612** 0.613	38	39 **0.695** 0.539	40 **0.610** 0.611
41 **0.528** 0.607	42 **0.537** 0.610	43	44 **0.612** 0.604	45 **0.530** 0.607	46 **0.606** 0.604	47 **0.543** 0.770	48 **0.465** 0.690	49 **0.617** 0.613	50 **0.533** 0.532
51 **0.534** 0.828	52 **0.613** 0.606	53 **0.613** 0.606	54 **0.681** 0.606	55 **0.610** 0.915	56 **0.609** 0.607	57 **0.532** 0.604	58 **0.537** 0.602	59	60 **0.624** 0.599

Soil depth zone	Mean	SE
0 – 12 inches	**0.626**	**0.009**
12 – 30 inches	0.678	0.014

Figure 19. Soil NH_4^+-N concentration (ppm, dry-soil basis) at two soil depth zones for each plot sampled on 20 Dec. 2002.

N→

70 ft

7 ft

5 ft

30 ft

1 **0.844** 0.460	2 **0.612** 0.376	3 **0.777** 0.382	4	5 **0.610** 0.614	6 **0.460** 0.458	7 **0.608** 0.454	8 **0.783** 0.456	9	10 **0.842** 0.611
11 **0.690** 0.380	12 **0.692** 0.461	13 **0.625** 0.382	14 **0.615** 0.379	15 **0.690** 0.384	16 **0.617** 0.385	17	18 **0.702** 0.382	19 **0.621** 0.386	20 **0.924** 0.456
21 **0.605** 0.379	22	23 **1.003** 0.382	24 **0.707** 0.457	25 **0.616** 0.525	26 **0.684** 0.385	27 **0.692** 0.378	28 **0.614** 0.385	29 **0.611** 0.388	30 **0.540** 0.382
31 **0.611** 0.449	32 **0.689** 0.381	33 **0.615** 0.458	34	35 **0.532** 0.455	36 **0.535** 0.386	37 **0.459** 0.383	38	39 **0.541** 0.385	40 **0.458** 0.382
41 **0.603** 0.455	42 **0.460** 0.381	43	44 **0.459** 0.377	45 **0.454** 0.455	46 **0.606** 0.378	47 **0.465** 0.385	48 **0.697** 0.383	49 **0.540** 0.383	50 **0.533** 0.380
51 **0.762** 0.376	52 **0.690** 0.379	53 **0.690** 0.454	54 **0.605** 0.379	55 **0.762** 0.381	56 **0.609** 0.379	57 **0.532** 0.377	58 **0.613** 0.376	59	60 **0.857** 0.449

Soil depth zone	Mean	SE
0 – 12 inches	**0.638**	**0.017**
12 – 30 inches	0.413	0.008

Table 21.1a. The effect of N-fertility source and rate on soil NO_3^--N and NH_4^+-N concentration on a dry soil basis at three soil depth zones from tall fescue on 9 Oct. 2003.

		NO_3^--N[z]			NH_4^+-N[z]		
		Soil depth zone			Soil depth zone		
Treatment		0-12 inches	12-24 inch	24-36 inches	0-12 inches	12-24 inches	24-36 inches
		ppm					
		ANOVA, RCB design, 13 treatments					
Source[y]	Rate[x]						
Ammonium nitrate	8	0.97	1.39	1.74	1.28	0.38	0.37
Milorganite	8	0.81	0.96	0.87	1.53	0.51	0.55
Nutralene	8	1.02	0.86	0.69	2.18	0.40	0.37
Polyon	8	1.33	1.09	0.67	1.82	0.56	0.37
Ammonium nitrate	6	0.79	0.70	0.74	1.56	0.38	0.37
Milorganite	6	0.85	0.61	0.69	1.24	0.38	0.37
Nutralene	6	0.70	0.71	0.67	1.58	0.38	0.37
Polyon	6	0.84	0.94	0.91	3.39	0.54	0.48
Ammonium nitrate	4	0.69	0.68	0.80	1.46	0.38	0.37
Milorganite	4	0.88	0.70	0.89	1.24	0.48	0.50
Nutralene	4	0.88	0.81	0.77	1.42	0.48	0.57
Polyon	4	0.90	0.87	0.74	1.77	0.50	0.54
Check	0	0.74	0.80	0.64	1.31	0.38	0.37
LSD, $P=0.05$[w]		NS	NS	0.42	NS	NS	NS
Randomized complete block design effects (P)							
Treatment		0.1519	0.4153	0.0017	0.4284	0.3664	0.4597
		ANOVA, 4 × 3 factorial design, 12 treatments					
Source[y]							
Ammonium nitrate		0.82	0.93	1.13	1.43	0.38	0.37
Milorganite		0.85	0.76	0.82	1.34	0.46	0.47
Nutralene		0.87	0.79	0.71	1.72	0.42	0.44
Polyon		1.02	0.97	0.77	2.33	0.53	0.46
LSD, $P=0.05$[w]		NS	NS	0.25	NS	NS	NS
Rate[x]							
8		1.03	1.08	0.99	1.70	0.46	0.41
6		0.80	0.74	0.76	1.94	0.42	0.40
4		0.84	0.77	0.80	1.47	0.46	0.50
LSD, $P=0.05$[w]		0.20	NS	NS	NS	NS	NS
Factorial design effects (P)							
Source (S)		0.2692	0.5631	0.0362	0.1873	0.0571	0.4173
Rate (R)		0.0441	0.0595	0.0770	0.5313	0.6188	0.2087
S x R		0.4649	0.7387	0.0061	0.5691	0.8467	0.5678

[z]Determined by KCl extraction of fresh soil (two cores per plot pooled by depth) and then converted to a dry weight basis.

[y]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[x]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[w]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Table 21.1b. Test of fixed effects for the effect of N-fertility source and rate on soil NO_3^--N and NH_4^+-N concentration on a dry soil basis at three soil depth zones from tall fescue on 9 Oct. 2003.

	NO_3^--N[z]				NH_4^+-N[z]			
	Numerator DF	Denominator DF	F-value	*P*-value	Numerator DF	Denominator DF	F-value	*P*-value
Split-plot design with auto-regressive correlative errors arranged in a RCB, 13 treatments								
Treatment (T)	12	77	2.35	0.0125	12	77	1.08	0.3913
Depth (D)[y]	2	77	0.30	0.7447	2	77	63.80	<0.0001
T x D	24	77	1.39	0.1401	24	77	1.03	0.4440
Split-plot design with auto-regressive correlative errors arranged in a 4 × 3 factorial design, 12 treatments								
Source (S)[x]	3	6	1.11	0.4168	3	6	2.15	0.1957
Rate (R)[w]	2	4	4.15	0.1058	2	4	0.19	0.8320
Depth (D)[y]	2	47	0.23	0.7931	2	47	57.16	<0.0001
S x R	6	12	1.87	0.1673	6	12	0.88	0.5398
S x D	6	47	1.96	0.0909	6	47	1.54	0.1867
R x D	4	47	0.37	0.8322	4	47	0.89	0.4775
S x R x D	12	47	1.49	0.1617	12	47	0.79	0.6536

[z]Determined by KCl extraction of fresh soil (two cores per plot pooled by depth) and then converted to a dry weight basis.

[y]Depths include: 0 to 12 inches, 12 to 24 inches, 24 to 36 inches.

[x]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[w]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

Table 21.2a. The effect of N-fertility source and rate on soil NO_3^--N and NH_4^+-N concentration on a dry soil basis at three soil depth zones from tall fescue on 6 Oct. 2004.

		NO_3^--N[z]			NH_4^+-N[z]		
		Soil depth zone			Soil depth zone		
Treatment		0-12 inches	12-24 inch	24-36 inches	0-12 inches	12-24 inches	24-36 inches
		ppm					
		ANOVA, RCB design, 13 treatments					
Source[y]	Rate[x]						
Ammonium nitrate	8	0.96	1.25	1.55	0.87	0.62	0.37
Milorganite	8	0.72	0.70	0.49	1.10	0.38	0.37
Nutralene	8	1.92	1.33	0.50	1.40	0.37	0.36
Polyon	8	1.76	0.90	0.74	0.90	0.38	0.39
Ammonium nitrate	6	0.63	0.65	0.62	0.93	0.37	0.37
Milorganite	6	0.43	0.41	0.44	0.84	0.38	0.37
Nutralene	6	0.51	0.47	0.45	0.95	0.37	0.37
Polyon	6	1.02	0.82	0.76	0.94	0.37	0.37
Ammonium nitrate	4	0.48	0.45	0.45	0.83	0.37	0.37
Milorganite	4	0.48	0.45	0.50	0.66	0.37	0.56
Nutralene	4	0.79	0.66	0.47	0.70	0.41	0.37
Polyon	4	0.46	0.45	0.42	0.92	0.37	0.37
Check	0	0.49	0.67	0.47	1.05	0.42	0.37
LSD, $P=0.05$[w]		0.82	NS	NS	NS	NS	NS
Randomized complete block design effects (P)							
Treatment		0.0091	0.1951	0.1614	0.4540	0.5380	0.5087
		ANOVA, 4 × 3 factorial design, 12 treatments					
Source[y]							
Ammonium nitrate		0.69	0.78	0.87	0.88	0.46	0.37
Milorganite		0.54	0.52	0.48	0.87	0.38	0.43
Nutralene		1.07	0.82	0.47	1.02	0.39	0.37
Polyon		1.08	0.72	0.64	0.92	0.37	0.38
LSD, $P=0.05$[w]		NS	NS	NS	NS	NS	NS
Rate[x]							
8		1.34	1.05	0.82	1.07	0.44	0.37
6		0.65	0.59	0.57	0.91	0.37	0.37
4		0.55	0.50	0.46	0.78	0.38	0.42
LSD, $P=0.05$[w]		0.43	0.38	NS	NS	NS	NS
Factorial design effects (P)							
Source (S)		0.0765	0.4889	0.2053	0.7685	0.4689	0.4398
Rate (R)		0.0017	0.0142	0.1364	0.1129	0.4288	0.3737
S x R		0.3067	0.7218	0.2843	0.5201	0.4200	0.4733

[z]Determined by KCl extraction of fresh soil (two cores per plot pooled by depth) and then converted to a dry weight basis.

[y]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[x]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[w]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Table 21.2b. Test of fixed effects for the effect of N-fertility source and rate on soil NO_3^--N and NH_4^+-N concentration on a dry soil basis at three soil depth zones from tall fescue on 6 Oct. 2004.

	NO_3^--N[z]				NH_4^+-N[z]			
	Numerator DF	Denominator DF	F-value	*P*-value	Numerator DF	Denominator DF	F-value	*P*-value
Split-plot design with auto-regressive correlative errors arranged in a RCB, 13 treatments								
Treatment (T)	12	78	2.02	0.0333	12	78	0.75	0.7022
Depth (D)[y]	2	78	3.31	0.0418	2	78	87.17	<0.0001
T x D	24	78	1.66	0.0490	24	78	1.11	0.3513
Split-plot design with auto-regressive correlative errors arranged in a 4 × 3 factorial design, 12 treatments								
Source (S)[x]	3	6	1.14	0.4056	3	6	0.10	0.9568
Rate (R)[w]	2	4	6.90	0.0504	2	4	2.68	0.1829
Depth (D)[y]	2	48	3.48	0.0388	2	48	77.19	<0.0001
S x R	6	12	0.69	0.6606	6	12	0.56	0.7525
S x D	6	48	2.34	0.0464	6	48	0.63	0.7052
R x D	4	48	1.35	0.2637	4	48	2.16	0.0876
S x R x D	12	48	1.45	0.1756	12	48	1.11	0.3754

[z]Determined by KCl extraction of fresh soil (two cores per plot pooled by depth) and then converted to a dry weight basis.

[y]Depths include: 0 to 12 inches, 12 to 24 inches, 24 to 36 inches.

[x]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[w]Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

Table 22.1. The effect of N-fertility source and rate on clipping yield (dry weight) of tall fescue from Nov. to Dec. 2002.

Treatment		4-week growth period (9 Nov. to 6 Dec. 2002)[z]				
		Sample date				4-week total yield
		15 Nov.	22 Nov.	29 Nov.	6 Dec.	
		---- $g \cdot m^{-2}$ per 7 d ----				$g \cdot m^{-2}$ per 28 d
ANOVA, RCB design, 13 treatments						
Source[y]	Rate[x]					
Ammonium nitrate	8	8.41	4.82	2.90	2.08	18.21
Milorganite	8	3.96	2.65	1.32	1.05	8.98
Nutralene	8	5.11	2.84	1.54	1.29	10.77
Polyon	8	3.48	2.41	1.78	1.29	8.95
Ammonium nitrate	6	5.72	3.64	1.77	1.25	12.38
Milorganite	6	3.68	2.18	1.16	0.66	7.68
Nutralene	6	3.47	2.21	1.09	0.85	7.61
Polyon	6	3.94	3.57	1.65	1.29	10.44
Ammonium nitrate	4	5.22	3.20	1.82	1.61	11.86
Milorganite	4	2.33	1.37	0.82	0.42	4.94
Nutralene	4	2.94	1.55	0.96	0.72	6.17
Polyon	4	2.98	2.10	1.13	0.86	7.07
Check	0	2.74	1.89	1.07	0.76	6.46
LSD, $P=0.05$[w]		2.13	1.34	0.85	0.74	4.64
Randomized complete block design effects (P)						
Treatment		0.0001	0.0004	0.0020	0.0052	0.0002
ANOVA, 4 × 3 factorial design, 12 treatments						
Source[y]						
Ammonium nitrate		6.45	3.89	2.16	1.65	14.15
Milorganite		3.32	2.06	1.10	0.71	7.20
Nutralene		3.84	2.20	1.19	0.95	8.18
Polyon		3.46	2.69	1.52	1.15	8.82
LSD, $P=0.05$[w]		1.27	0.81	0.50	0.43	2.77
Rate[x]						
8		5.24	3.18	1.89	1.43	11.73
6		4.20	2.90	1.42	1.01	9.53
4		3.37	2.06	1.18	0.90	7.51
LSD, $P=0.05$[w]		1.10	0.70	0.43	0.37	2.40
Factorial design effects (P)						
Source (S)		<0.0001	0.0002	0.0005	0.0008	<0.0001
Rate (R)		0.0061	0.0074	0.0078	0.0173	0.0045
S x R		0.4669	0.4047	0.6981	0.7266	0.5276

[z] Clipping yields taken 4 weeks after each fertilizer application.

[y] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[x] Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[w] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 22.2. The effect of N-fertility source and rate on clipping yield (dry weight) of tall fescue from Mar. to Apr. 2003.

Treatment		4-week growth period (22 Mar. to 18 Apr. 2003)[z]				
		Sample date				4-week total yield
		28 Mar.	4 Apr.	11 Apr.	18 Apr.	
		g·m⁻² per 7 d				*g·m⁻² per 28 d*
ANOVA, RCB design, 13 treatments						
Source[y]	Rate[x]					
Ammonium nitrate	8	9.58	6.42	6.47	5.07	27.54
Milorganite	8	2.39	1.34	1.55	1.46	6.74
Nutralene	8	3.61	2.17	2.11	2.44	10.34
Polyon	8	5.50	4.28	4.29	5.35	19.41
Ammonium nitrate	6	5.13	2.76	3.28	2.37	13.54
Milorganite	6	1.66	1.15	1.01	0.93	4.75
Nutralene	6	1.86	1.34	1.84	1.69	6.73
Polyon	6	3.09	1.86	2.95	3.16	11.04
Ammonium nitrate	4	3.88	2.70	2.92	2.21	11.71
Milorganite	4	1.31	0.53	0.79	0.58	3.20
Nutralene	4	1.28	1.17	1.14	0.81	4.39
Polyon	4	2.35	1.66	1.53	2.07	7.61
Check	0	1.79	0.63	1.13	0.73	4.28
LSD, $P=0.05$[w]		2.26	1.49	1.80	1.35	5.63
Randomized complete block design effects (*P*)						
Treatment		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
ANOVA, 4 × 3 factorial design, 12 treatments						
Source[y]						
Ammonium nitrate		6.20	3.96	4.22	3.22	17.59
Milorganite		1.79	1.01	1.12	0.99	4.90
Nutralene		2.25	1.56	1.70	1.65	7.15
Polyon		3.64	2.60	2.92	3.53	12.69
LSD, $P=0.05$[w]		1.36	0.90	1.08	0.81	3.40
Rate[x]						
8		5.27	3.55	3.61	3.58	16.01
6		2.94	1.77	2.27	2.04	9.01
4		2.20	1.51	1.59	1.42	6.73
LSD, $P=0.05$[w]		1.18	0.78	0.94	0.70	2.95
Factorial design effects (*P*)						
Source (S)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Rate (R)		<0.0001	<0.0001	0.0004	<0.0001	<0.0001
S x R		0.1821	0.0408	0.2047	0.1351	0.0476

[z] Clipping yields taken 4 weeks after each fertilizer application.

[y] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[x] Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[w] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 22.3. The effect of N-fertility source and rate on clipping yield (dry weight) of tall fescue from June to July 2003.

Treatment		4-week growth period (7 June to 4 July 2003)[z]				
		Sample date				4-week total yield
		13 June	20 June	27 June	4 July	
		$g \cdot m^{-2}$ per 7 d				$g \cdot m^{-2}$ per 28 d
ANOVA, RCB design, 13 treatments						
Source[y]	Rate[x]					
Ammonium nitrate	8	20.84	13.61	10.71	12.04	57.20
Milorganite	8	10.95	9.11	9.29	8.91	38.25
Nutralene	8	14.40	9.84	11.25	10.26	45.75
Polyon	8	15.79	12.82	14.17	13.69	56.47
Ammonium nitrate	6	13.17	9.28	9.73	7.81	39.99
Milorganite	6	6.20	5.50	4.61	4.82	21.13
Nutralene	6	7.17	5.08	5.81	5.94	24.00
Polyon	6	11.41	8.93	12.09	11.01	43.44
Ammonium nitrate	4	8.03	5.46	6.71	5.97	26.18
Milorganite	4	2.81	2.07	3.07	2.72	10.67
Nutralene	4	3.17	3.74	3.17	3.26	13.34
Polyon	4	5.75	4.94	5.70	5.60	21.99
Check	0	1.81	1.60	1.80	1.47	6.68
LSD, $P=0.05$[w]		3.65	3.06	2.49	2.92	10.07
Randomized complete block design effects (*P*)						
Treatment		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
ANOVA, 4 × 3 factorial design, 12 treatments						
Source[y]						
Ammonium nitrate		14.01	9.45	9.05	8.61	41.12
Milorganite		6.65	5.56	5.66	5.48	23.35
Nutralene		8.25	6.22	6.74	6.49	27.70
Polyon		10.98	8.89	10.65	10.10	40.64
LSD, $P=0.05$[w]		2.20	1.83	1.49	1.76	6.08
Rate[x]						
8		15.49	11.34	11.36	11.23	49.42
6		9.49	7.19	8.06	7.40	32.14
4		4.94	4.05	4.66	4.39	18.05
LSD, $P=0.05$[w]		1.91	1.58	1.29	1.53	5.27
Factorial design effects (*P*)						
Source (S)		<0.0001	0.0001	<0.0001	<0.0001	<0.0001
Rate (R)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
S x R		0.6234	0.8984	0.0301	0.7174	0.7353

[z] Clipping yields taken 4 weeks after each fertilizer application.

[y] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[x] Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[w] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 22.4. The effect of N-fertility source and rate on clipping yield (dry weight) of tall fescue from Sept. to Oct. 2003.

Treatment		3-week growth period (6 to 12 Sept. and 20 Sept. to 3 Oct. 2003)[z]				
		Sample date				4-week
		12 Sept.	19 Sept.	26 Sept.	3 Oct.	total yield
		g·m⁻² per 7 d				*g·m⁻² per 21 d*
ANOVA, RCB design, 13 treatments						
Source[y]	Rate[x]					
Ammonium nitrate	8	14.44	–	26.41	19.55	60.40
Milorganite	8	17.04	–	33.12	18.94	69.10
Nutralene	8	22.19	–	21.11	23.01	66.31
Polyon	8	15.77	–	35.47	24.26	75.50
Ammonium nitrate	6	15.18	–	29.84	16.82	61.83
Milorganite	6	12.04	–	25.32	14.89	52.25
Nutralene	6	11.29	–	18.52	15.69	45.50
Polyon	6	16.58	–	25.33	19.97	61.88
Ammonium nitrate	4	10.76	–	23.34	11.56	45.66
Milorganite	4	8.11	–	16.13	12.17	36.42
Nutralene	4	11.29	–	17.96	16.12	45.36
Polyon	4	10.84	–	19.87	15.74	46.45
Check	0	3.04	–	8.79	3.82	15.64
LSD, $P=0.05$[w]		4.28	–	11.10	4.32	14.18
Randomized complete block design effects (P)						
Treatment		<0.0001	–	0.0016	<0.0001	<0.0001
ANOVA, 4 × 3 factorial design, 12 treatments						
Source[y]						
Ammonium nitrate		13.46	–	26.53	15.98	55.96
Milorganite		12.40	–	24.86	15.33	52.59
Nutralene		14.92	–	19.20	18.27	52.39
Polyon		14.40	–	26.89	19.99	61.28
LSD, $P=0.05$[w]		NS	–	NS	2.53	NS
Rate[x]						
8		17.36	–	29.03	21.44	67.83
6		13.77	–	24.75	16.84	55.37
4		10.25	–	19.32	13.90	43.47
LSD, $P=0.05$[w]		2.23	–	5.72	2.19	7.30
Factorial design effects (P)						
Source (S)		0.2234	–	0.0853	0.0024	0.1319
Rate (R)		<0.0001	–	0.0061	<0.0001	<0.0001
S x R		0.0106	–	0.3659	0.6011	0.2327

[z] Clipping yields taken 4 weeks after each fertilizer application; data not available for 13 to 19 Sept. 2003.

[y] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[x] Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[w] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 22.5. The effect of N-fertility source and rate on clipping yield (dry weight) of tall fescue from Nov. to Dec. 2003.

Treatment		4-week growth period (8 Nov. to 5 Dec. 2003)[z]				
		Sample date				4-week total yield[y]
		14 Nov.	21 Nov.	28 Nov.	5 Dec.	
		$g \cdot m^{-2}$ *per 7 d*				$g \cdot m^{-2}$ *per 28 d*
		ANOVA, RCB design, 13 treatments				
Source[x]	Rate[w]					
Ammonium nitrate	8	20.12	11.57	6.56	3.92	39.25
Milorganite	8	17.02	11.37	5.59	7.06	41.05
Nutralene	8	16.42	10.52	4.76	6.65	38.36
Polyon	8	14.21	10.66	5.39	6.51	38.99
Ammonium nitrate	6	18.31	13.67	5.37	6.37	43.71
Milorganite	6	11.22	6.93	3.78	4.43	26.36
Nutralene	6	12.81	10.19	4.14	4.27	33.35
Polyon	6	12.72	9.46	4.66	5.87	32.71
Ammonium nitrate	4	11.39	7.47	3.01	4.01	25.87
Milorganite	4	10.16	5.82	2.51	2.47	20.96
Nutralene	4	9.78	6.57	3.51	2.27	23.54
Polyon	4	8.76	6.07	3.09	3.48	21.40
Check	0	3.01	1.88	0.99	0.71	6.71
LSD, $P = 0.05$[v]		3.31	2.56	1.55	2.43	5.78
Randomized complete block design effects (*P*)						
Treatment		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
		ANOVA, 4 × 3 factorial design, 12 treatments				
Source[x]						
Ammonium nitrate		16.60	10.90	4.98	4.84	36.01
Milorganite		12.80	8.04	3.96	4.65	29.46
Nutralene		13.00	9.09	4.14	4.62	32.41
Polyon		11.90	8.73	4.38	5.18	30.31
LSD, $P = 0.05$[v]		1.99	1.52	NS	NS	3.37
Rate[w]						
8		16.94	11.03	5.58	6.15	39.45
6		13.76	10.06	4.49	5.30	34.08
4		10.02	6.48	3.03	3.11	22.90
LSD, $P = 0.05$[v]		1.73	1.31	0.81	1.24	2.91
Factorial design effects (*P*)						
Source (S)		0.0002	0.0040	0.1545	0.6626	0.0022
Rate (R)		<0.0001	<0.0001	<0.0001	0.0001	<0.0001
S x R		0.2615	0.0466	0.4701	0.0968	0.0037

[z] Clipping yields taken 4 weeks after each fertilizer application.

[y] Due to missing data, 4-week total yield may not equal total of weekly yields. Any plot which has missing data in any week has been eliminated from the cumulative yield calculations for that growth period.

[x] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[w] Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[v] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P = 0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 22.6. The effect of N-fertility source and rate on clipping yield (dry weight) of tall fescue from Mar. to Apr. 2004.

Treatment		4-week growth period (20 Mar. to 16 Apr. 2004)[z]				
		Sample date				4-week
		26 Mar.	2 Apr.	9 Apr.	16 Apr.	Total yield
		$g{\cdot}m^{-2}$ per 7 d				$g{\cdot}m^{-2}$ per 28 d
ANOVA, RCB design, 13 treatments						
Source[y]	Rate[x]					
Ammonium nitrate	8	33.09	27.47	27.97	19.67	108.20
Milorganite	8	23.12	24.80	30.31	18.97	97.20
Nutralene	8	25.77	25.37	30.54	19.19	100.86
Polyon	8	22.87	22.05	32.56	21.14	98.62
Ammonium nitrate	6	25.34	24.07	30.49	17.73	97.63
Milorganite	6	12.82	15.56	20.39	13.57	62.34
Nutralene	6	14.07	15.44	22.91	12.90	65.31
Polyon	6	19.08	19.13	29.44	18.89	86.54
Ammonium nitrate	4	13.76	14.07	18.59	12.72	59.14
Milorganite	4	6.85	9.08	11.89	9.11	36.94
Nutralene	4	10.96	12.87	15.22	11.20	50.26
Polyon	4	10.34	14.31	17.56	13.33	55.54
Check	0	1.64	1.79	3.33	2.31	9.07
LSD, $P=0.05$[w]		5.76	4.68	6.43	3.64	12.42
Randomized complete block design effects (*P*)						
Treatment		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
ANOVA, 4 × 3 factorial design, 12 treatments						
Source[y]						
Ammonium nitrate		24.06	21.87	25.68	16.71	88.32
Milorganite		14.27	16.48	20.86	13.88	65.49
Nutralene		16.93	17.89	22.89	14.43	72.14
Polyon		17.43	18.50	26.52	17.79	80.23
LSD, $P=0.05$[w]		3.46	2.80	3.87	2.19	7.46
Rate[x]						
8		26.21	24.92	30.34	19.74	101.22
6		17.83	18.55	25.80	15.77	77.99
4		10.48	12.58	15.81	11.59	50.47
LSD, $P=0.05$[w]		3.00	2.43	3.36	1.90	6.46
Factorial design effects (*P*)						
Source (S)		<0.0001	0.0036	0.0205	0.0024	<0.0001
Rate (R)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
S x R		0.2905	0.0875	0.2068	0.5142	0.0258

[z] Clipping yields taken 4 weeks after each fertilizer application.

[y] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[x] Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[w] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 22.7. The effect of N-fertility source and rate on clipping yield (dry weight) of tall fescue from June to July 2004.

Treatment		4-week growth period (5 June to 2 July 2004)[z]				
		Sample date				4-week total yield
		11 June	18 June	25 June	2 July	
		g·m⁻² per 7 d				*g·m⁻² per 28 d*
ANOVA, RCB design, 13 treatments						
Source[y]	Rate[x]					
Ammonium nitrate	8	23.19	17.45	16.33	11.39	68.35
Milorganite	8	21.32	16.31	17.04	16.65	71.31
Nutralene	8	21.46	16.81	18.44	14.66	71.36
Polyon	8	23.28	21.26	18.51	16.54	79.58
Ammonium nitrate	6	21.65	10.86	9.28	8.08	49.86
Milorganite	6	13.41	11.04	9.58	10.04	44.07
Nutralene	6	15.75	13.69	11.21	11.15	51.81
Polyon	6	16.24	15.26	15.09	15.47	62.06
Ammonium nitrate	4	14.36	9.03	7.44	8.15	38.98
Milorganite	4	10.17	7.47	7.36	6.49	31.49
Nutralene	4	9.11	8.45	8.31	6.20	32.07
Polyon	4	11.39	10.44	9.66	8.96	40.34
Check	0	2.48	1.55	2.08	2.08	8.19
LSD, $P=0.05$[w]		4.68	5.04	3.85	3.85	13.38
Randomized complete block design effects (P)						
Treatment		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
ANOVA, 4 × 3 factorial design, 12 treatments						
Source[y]						
Ammonium nitrate		19.73	12.44	11.02	9.20	52.40
Milorganite		14.96	11.61	11.32	11.06	48.96
Nutralene		15.44	12.98	12.65	10.67	51.75
Polyon		16.97	15.65	14.42	13.62	60.66
LSD, $P=0.05$[w]		2.81	NS	2.31	2.32	8.08
Rate[x]						
8		22.31	17.96	17.58	14.81	72.65
6		16.76	12.71	11.29	11.18	51.95
4		11.26	8.85	8.19	7.43	35.72
LSD, $P=0.05$[w]		2.43	2.63	2.00	2.01	7.00
Factorial design effects (P)						
Source (S)		0.0066	0.0594	0.0207	0.0048	0.0353
Rate (R)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
S x R		0.5747	0.9331	0.7457	0.1146	0.7917

[z] Clipping yields taken 4 weeks after each fertilizer application.

[y] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[x] Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[w] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 22.8. The effect of N-fertility source and rate on clipping yield (dry weight) of tall fescue from Sept. to Oct. 2004.

Treatment		4-week growth period (4 Sept. to 1 Oct. 2004)[z]				
		Sample date				4-week total yield[y]
		10 Sept.	17 Sept.	24 Sept.	1 Oct.	
		g·m⁻² per 7 d				*g·m⁻² per 28 d*
		ANOVA, RCB design, 13 treatments				
Source[x]	Rate[w]					
Ammonium nitrate	8	33.37	22.44	16.69	20.32	92.82
Milorganite	8	28.67	16.83	21.80	17.31	84.61
Nutralene	8	42.38	18.12	19.15	21.31	100.96
Polyon	8	30.99	19.93	18.81	20.68	90.41
Ammonium nitrate	6	28.75	14.74	15.48	15.52	74.49
Milorganite	6	26.70	11.72	14.92	19.50	72.84
Nutralene	6	24.64	19.74	16.87	17.88	76.82
Polyon	6	30.84	17.67	18.77	20.53	87.81
Ammonium nitrate	4	32.85	16.38	15.85	15.53	80.61
Milorganite	4	21.16	10.09	12.29	10.98	54.53
Nutralene	4	27.22	13.03	14.77	13.86	68.88
Polyon	4	31.51	13.76	16.44	18.20	79.91
Check	0	8.86	6.05	7.06	7.52	29.49
LSD, $P=0.05$[v]		10.08	6.88	4.31	4.47	18.96
Randomized complete block design effects (P)						
Treatment		<0.0001	0.0024	<0.0001	<0.0001	<0.0001
		ANOVA, 4 × 3 factorial design, 12 treatments				
Source[x]						
Ammonium nitrate		31.37	17.54	15.95	16.96	81.82
Milorganite		25.51	12.88	16.34	15.93	70.66
Nutralene		31.42	16.96	16.93	17.66	82.71
Polyon		31.12	16.87	17.93	19.72	85.65
LSD, $P=0.05$[v]		NS	NS	NS	2.56	10.79
Rate[x]						
8		34.51	19.24	19.12	20.01	92.87
6		27.80	16.25	16.62	18.31	78.44
4		28.36	13.33	14.95	14.84	71.47
LSD, $P=0.05$[v]		NS	3.54	2.17	2.21	9.32
Factorial design effects (P)						
Source (S)		0.0891	0.0834	0.3542	0.0288	0.0235
Rate (R)		0.0741	0.0098	0.0025	0.0002	0.0006
S x R		0.1042	0.5816	0.1652	0.1178	0.3143

[z] Clipping yields taken 4 weeks after each fertilizer application.

[y] Due to missing data, 4-week total yield may not equal total of weekly yields. Any plot which has missing data in any week has been eliminated from the cumulative yield calculations for that growth period.

[x] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[w] Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[v] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 23.1. The effect of N-fertility source and rate on 4-week total clipping yield (dry weight), clipping yield TKN concentration, and N uptake of tall fescue from Nov. 2002 to Oct. 2003.

		4-week growth period[z]											
		9 Nov. to 6 Dec. 2002			22 Mar. to 18 Apr. 2003			7 June to 4 July 2003			6 to 12 Sept., 20 Sept. to 3 Oct. 2003[y]		
Treatment		Yield	TKN	N uptake[x]	Yield	TKN	N uptake[x]	Yield	TKN	N uptake[x]	Yield	TKN	N uptake[x]
		g·m⁻² per 28 d	---- *%* ----	*g·m⁻² per 28 d*	*g·m⁻² per 28 d*	---- *%* ----	*g·m⁻² per 28 d*	*g·m⁻² per 28 d*	---- *%* ----	*g·m⁻² per 28 d*	*g·m⁻² per 21 d*	---- *%* ----	*g·m⁻² per 21 d*
					ANOVA, RCB design, 13 treatments								
Source[x]	Rate[v]												
Ammonium nitrate	8	18.21	4.16	0.76	27.54	3.51	0.91	57.20	3.68	2.00	60.40	4.55	2.78
Milorganite	8	8.98	3.77	0.31	6.74	2.84	0.19	38.25	3.37	1.29	69.10	4.45	3.09
Nutralene	8	10.77	3.64	0.40	10.34	3.03	0.32	45.75	3.58	1.64	66.31	4.56	3.02
Polyon	8	8.95	3.86	0.39	19.41	3.33	0.65	56.47	3.62	2.05	75.50	4.72	3.57
Ammonium nitrate	6	12.38	3.94	0.49	13.54	3.16	0.43	39.99	3.37	1.36	61.83	4.37	2.71
Milorganite	6	7.68	3.63	0.28	4.75	2.73	0.13	21.13	2.65	0.58	52.25	4.39	2.29
Nutralene	6	7.61	3.48	0.27	6.73	2.80	0.19	24.00	3.15	0.77	45.50	4.22	1.93
Polyon	6	10.44	3.67	0.38	11.04	2.94	0.32	43.44	3.48	1.51	61.88	4.50	2.81
Ammonium nitrate	4	11.86	3.90	0.47	11.71	3.01	0.36	26.18	3.08	0.81	45.66	3.95	1.80
Milorganite	4	4.94	3.28	0.16	3.20	2.41	0.08	10.67	3.88	0.43	36.42	4.06	1.50
Nutralene	4	6.17	3.47	0.22	4.39	2.53	0.11	13.34	3.01	0.40	45.36	4.03	1.85
Polyon	4	7.07	3.48	0.25	7.61	2.78	0.22	21.99	3.04	0.67	46.45	4.20	1.96
Check	0	6.46	3.32	0.22	4.28	2.38	0.11	6.68	2.68	0.18	15.64	3.58	0.56
LSD, $P=0.05$[u]		4.64	0.24	0.19	5.63	0.22	0.20	10.07	0.81	0.41	14.18	0.25	0.66
Randomized complete block design effects (P)													
Treatment		0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
					ANOVA, 4×3 factorial design, 12 treatments								
Source[x]													
Ammonium nitrate		14.15	4.00	0.57	17.59	3.20	0.53	41.12	3.35	1.33	55.96	4.29	2.43
Milorganite		7.20	3.54	0.25	4.90	2.64	0.13	23.35	3.24	0.80	52.59	4.30	2.29
Nutralene		8.18	3.53	0.29	7.15	2.79	0.21	27.70	3.25	0.94	52.39	4.27	2.27
Polyon		8.82	3.65	0.34	12.69	3.02	0.40	40.64	3.38	1.41	61.28	4.47	2.78
LSD, $P=0.05$[u]		2.77	0.14	0.11	3.40	0.13	0.12	6.08	NS	0.25	NS	0.15	0.39
Rate[v]													
8		11.73	3.86	0.48	16.01	3.18	0.51	49.42	3.55	1.73	67.83	4.57	3.12
6		9.53	3.68	0.36	9.01	2.91	0.27	32.14	3.16	1.05	55.37	4.37	2.43
4		7.51	3.53	0.27	6.73	2.68	0.19	18.05	3.21	0.59	43.47	4.06	1.78
LSD, $P=0.05$[u]		2.40	0.12	0.10	2.95	0.12	0.11	5.27	NS	0.21	7.30	0.13	0.34
Factorial design effects (P)													
Source (S)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.8877	<0.0001	0.1319	0.0273	0.0433
Rate (R)		0.0045	<0.0001	0.0010	<0.0001	<0.0001	<0.0001	<0.0001	0.1082	<0.0001	<0.0001	<0.0001	<0.0001
S x R		0.5276	0.4333	0.6414	0.0476	0.6717	0.0721	0.7353	0.1483	0.3967	0.2327	0.6985	0.2696

[z] Clipping yields taken four consecutive weeks beginning 4 weeks after each fertilizer application.

[y] Data not available for 13 to 19 Sept. 2003; total yield calculated over 21 d.

[x] Calculated as 4-week total yield mass (or 3-week total yield mass for the Sept. to Oct. 2003 period)x TKN concentration of pooled 4-week total yield mass.

[w] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[v] Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[u] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Table 23.2. The effect of N-fertility source and rate on 4-week total clipping yield (dry weight), clipping yield TKN concentration, and N uptake of tall fescue from Nov. 2003 to Oct. 2004.

		4-week growth period[z]											
		8 Nov. to 5 Dec. 2003			20 Mar. to 16 Apr. 2004			5 June to 2 July 2004			4 Sept. to 1 Oct. 2004		
Treatment		Yield	TKN	N uptake[y]	Yield	TKN	N uptake[y]	Yield	TKN	N uptake[y]	Yield	TKN	N uptake[y]
		$g \cdot m^{-2}$ per 28 d	---- % ----	*$g \cdot m^{-2}$ per 28 d*	*$g \cdot m^{-2}$ per 28 d*	---- % ----	*$g \cdot m^{-2}$ per 28 d*	*$g \cdot m^{-2}$ per 28 d*	---- % ----	*$g \cdot m^{-2}$ per 28 d*	*$g \cdot m^{-2}$ per 28 d*	---- % ----	*$g \cdot m^{-2}$ per 28 d*
ANOVA, RCB design, 13 treatments													
Source[x]	Rate[w]												
Ammonium nitrate	8	20.12	4.51	1.77	108.20	4.33	4.68	68.35	3.68	2.54	86.96	4.39	3.78
Milorganite	8	17.02	4.47	1.84	97.20	4.25	4.14	71.31	3.75	2.67	84.61	4.54	3.84
Nutralene	8	16.42	4.41	1.69	100.86	4.24	4.29	71.36	3.76	2.70	100.96	4.63	4.67
Polyon	8	14.21	4.68	1.82	98.62	4.22	4.17	79.58	3.89	3.09	90.41	4.67	4.23
Ammonium nitrate	6	18.31	4.43	1.94	97.63	4.09	4.00	49.86	3.49	1.76	74.49	4.34	3.29
Milorganite	6	11.22	4.20	1.13	62.34	3.90	2.47	44.07	3.36	1.48	72.84	4.32	3.15
Nutralene	6	12.81	4.19	1.40	65.31	3.81	2.49	51.81	3.40	1.77	74.66	4.32	3.22
Polyon	6	12.72	4.27	1.40	86.54	4.15	3.61	62.06	3.70	2.30	87.81	4.46	3.91
Ammonium nitrate	4	11.39	4.02	1.04	59.14	3.85	2.28	38.98	3.25	1.28	80.61	4.32	3.49
Milorganite	4	10.16	3.96	0.83	36.94	3.51	1.30	31.49	3.18	1.00	54.53	3.96	2.16
Nutralene	4	9.78	4.00	0.95	50.26	3.72	1.89	32.07	3.25	1.05	68.88	4.30	2.95
Polyon	4	8.76	3.98	0.86	55.54	3.80	2.12	40.34	3.33	1.36	79.91	4.32	3.46
Check	0	3.01	3.37	0.23	9.07	3.40	0.31	8.19	2.89	0.24	29.49	3.77	1.12
LSD, $P=0.05$[v]		3.31	0.24	0.29	12.42	0.21	0.60	13.38	0.23	0.57	18.55	0.38	0.92
Randomized complete block design effects (*P*)													
Treatment		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0019	<0.0001
ANOVA, 4 × 3 factorial design, 12 treatments													
Source[y]													
Ammonium nitrate		16.60	4.30	1.57	88.32	4.09	3.65	52.40	3.47	1.86	80.07	4.35	3.50
Milorganite		12.80	4.21	1.27	65.49	3.89	2.64	48.96	3.43	1.72	70.66	4.27	3.05
Nutralene		13.00	4.22	1.38	72.14	3.92	2.89	51.75	3.47	1.84	81.50	4.41	3.61
Polyon		11.90	4.28	1.32	80.23	4.06	3.30	60.66	3.64	2.25	85.65	4.47	3.83
LSD, $P=0.05$[v]		1.99	NS	0.17	7.46	0.13	0.36	8.08	0.13	0.34	10.66	NS	0.54
Rate[w]													
8		16.94	4.51	1.78	101.22	4.26	4.32	72.65	3.77	2.75	91.52	4.56	4.17
6		13.76	4.28	1.47	77.99	3.99	3.14	51.95	3.49	1.83	77.76	4.36	3.41
4		10.02	3.99	0.92	50.47	3.72	1.90	35.72	3.25	1.17	71.47	4.24	3.04
LSD, $P=0.05$[v]		1.73	0.12	0.14	6.46	0.11	0.31	7.00	0.12	0.30	9.20	0.20	0.47
Factorial design effects (*P*)													
Source (S)		0.0002	0.1754	0.0036	<0.0001	0.0053	<0.0001	0.0353	0.0162	0.0202	0.0327	0.3006	0.0276
Rate (R)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0011	0.0084	0.0003
S x R		0.2615	0.5143	0.0058	0.0258	0.1194	0.0324	0.7917	0.7018	0.7982	0.2021	0.6748	0.1957

[z] Clipping yields taken four consecutive weeks beginning 4 weeks after each fertilizer application.

[y] Calculated as 4-week total yield mass x TKN concentration of pooled 4-week total yield mass.

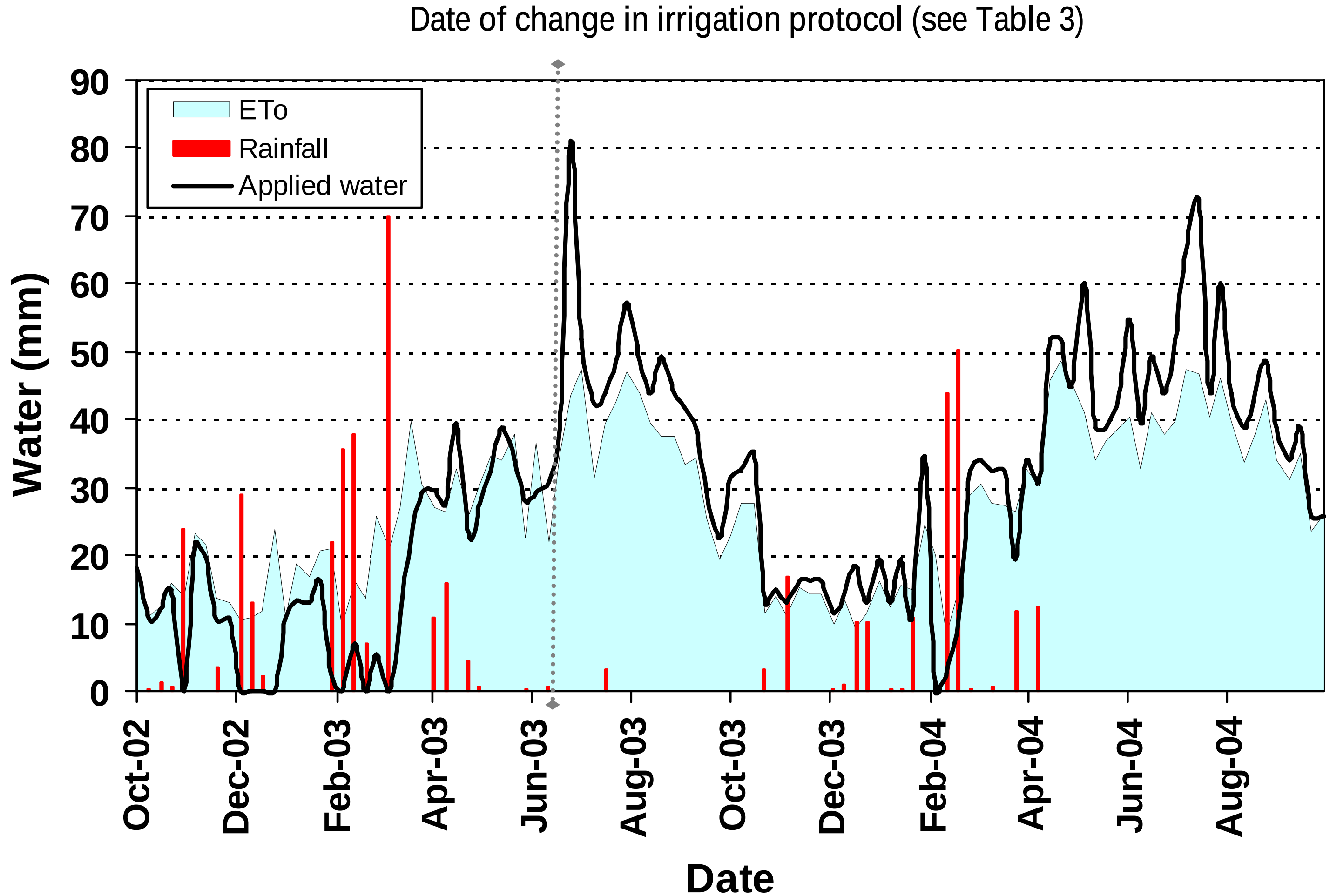
[x] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[w] Annual rates as lb N/1000 ft^2 per year. Applied 18 Oct. 2002, 3 Mar. 2003, 15-16 May 2003, 15 Aug. 2003, 17 Oct. 2003, 2 Mar. 2004, 13 May 2004, and 13 Aug. 2004.

[v] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Note: Prior to 2 July 2003, the irrigation protocol was (100% ETcrop/DU) minus rainfall; on 2 July 2003 it was changed to 110% ET_o (Table 3, Fig. 20).

Figure 20. Weekly irrigation, ET_o, and rainfall from 16 Oct. 2002 to 19 Oct. 2004.



The plot is irrigated at 110% reference evapotranspiration (ET_o) beginning on 2 July 2003. [Note that from 16 Oct. 2002 to 1 July 2003 the plot was irrigated at 100% ET_{crop}/DU minus rainfall, where ET_{crop} = ET_o x crop coefficient (K_c) (Table 4) and DU = irrigation system uniformity (Table 4).] The amount of irrigation is determined each week based on the previous 7 d cumulative ET_o, obtained from an on-site CIMIS station, and is applied in three irrigation events per week. Irrigation events are cycled to prevent runoff. Rain is not subtracted from the irrigation amount but may result in a cancellation of an irrigation event.

Table 24a. Weather and other information used to determine the weekly irrigation amount in Riverside, Calif., from 16 Oct. 2002 to 1 July 2003. Irrigation protocol = (100% ET_{crop}/DU) minus rainfall.

Week	Irrigation applied[z]	Previous 7 d total			Distribution uniformity (DU)	Previous 7-d 100% ET_{crop}/DU
		ET_o	100% ET_{crop}	Rainfall		
	---------- *mm* ----------				----- % -----	----- *mm* -----
16-22 Oct. 2002	18.1	18.04	13.53	0.0	76	17.80
23-29 Oct. 2002	10.6	11.16	8.37	0.2	76	11.01
30 Oct.-5 Nov. 2002	12.1	12.56	9.42	1.3	76	12.39
6-12 Nov. 2002	15.1	15.98	11.03	0.6	76	14.51
13-19 Nov. 2002	0.0	13.89	9.58	23.8	76	12.61
20-26 Nov. 2002	21.6	23.07	15.92	0.0	76	20.95
27 Nov.-3 Dec. 2002	19.6	21.72	14.99	0.0	76	19.72
4-10 Dec. 2002	10.6	13.74	8.24	3.4	76	10.85
11-17 Dec. 2002	10.6	13.13	7.88	0.0	76	10.37
18-24 Dec. 2002	0.0	10.41	6.25	29.0	76	8.22
25-31 Dec. 2002	0.0	10.89	6.53	12.9	76	8.60
1-7 Jan. 2003	0.0	11.77	7.18	2.3	76	9.45
8-14 Jan. 2003	0.0	23.82	14.53	0.0	76	19.12
15-21 Jan. 2003	10.8	10.66	6.50	0.0	83	7.83
22-28 Jan. 2003	13.3	18.88	11.52	0.0	83	13.88
29 Jan.-4 Feb. 2003	13.0	16.89	10.30	0.0	83	12.41
5-11 Feb. 2003	16.2	20.55	13.15	0.0	83	15.85
12-18 Feb. 2003	2.7	20.99	13.43	22.0	83	16.19
19-25 Feb. 2003	0.0	9.60	6.14	35.7	83	7.40
26 Feb.-4 Mar. 2003	7.0	16.36	10.47	38.0	83	12.61
5-11 Mar. 2003	0.0	13.76	10.32	7.1	83	12.43
12-18 Mar. 2003	5.4	25.77	19.33	0.1	83	23.29
19-25 Mar. 2003	0.0	20.98	15.74	70.0	83	18.96
26 Mar.-1 Apr. 2003	10.8	26.99	20.24	0.0	83	24.39
2-8 Apr. 2003	22.2	39.76	41.35	0.0	83	49.82
9-15 Apr. 2003	29.2	30.46	31.68	0.0	83	38.17
16-22 Apr. 2003	29.7	26.91	27.99	10.7	83	33.72
23-29 Apr. 2003	27.6	26.35	27.40	16.0	83	33.02
30 Apr.-6 May 2003	39.5	32.79	34.10	0.0	83	41.09
7-13 May 2003	22.7	25.93	24.63	4.6	83	29.68
14-20 May 2003	27.6	30.62	29.09	0.7	83	35.05
21-27 May 2003	32.4	34.74	33.00	0.0	83	39.76
28 May-3 June 2003	38.9	34.01	32.31	0.0	83	38.93
4-10 June 2003	34.1	38.00	33.44	0.0	83	40.29
11-17 June 2003	28.1	22.65	19.93	0.2	83	24.01
18-24 June 2003	29.2	36.59	32.20	0.0	83	38.79
25 June-1 July 2003	30.8	22.08	19.43	0.5	83	23.41
Total	589.5	802.50	657.14	279.1	–	806.58

[z] Actual amount of irrigation applied in a given week may differ from (100% ET_{crop}/DU) minus rainfall in order to maintain representative turfgrass and due to limitations of the irrigation clock which require cycled run times to be rounded to the nearest whole minute. Any surplus or deficit irrigation is balanced such that on an annual basis the total irrigation applied is (100% ET_{crop}/DU) minus rainfall. The calculations to determine the amount of irrigation each week are based on the previous 7 d cumulative ET_o, obtained from an on-site CIMIS station.

Note: Total irrigation applied = 589.5 mm; total (100% ET_{crop}/DU) minus total rainfall = 527.5 mm.
Note: (Total irrigation applied / total ET_o) x 100 = 73%.
Note: [(Total irrigation applied + total rainfall) / total ET_o] x 100 = 108%.

Table 24b. Weather and other information used to determine the weekly irrigation amount in Riverside, Calif., from 2 July 2003 to 12 Oct. 2004. Irrigation protocol = 110% ET_o.

Week	Irrigation applied[z]	Previous 7 d ET_o	Previous 7 d rainfall
	mm		
2-8 July 2003	38.9	35.07	0.0
9-15 July 2003	81.1	43.67	0.0
16-22 July 2003	51.9	47.24	0.0
23-29 July 2003	42.2	31.60	0.0
30 July-5 Aug. 2003	43.8	39.48	3.3
6-12 Aug. 2003	48.6	42.50	0.0
13-19 Aug. 2003	57.3	47.12	0.0
20-26 Aug. 2003	48.6	43.79	0.0
27 Aug.-2 Sept. 2003	43.8	39.28	0.0
3-9 Sept. 2003	49.2	37.64	0.0
10-16 Sept. 2003	43.8	37.61	0.0
17-23 Sept. 2003	41.6	33.28	0.0
24-30 Sept. 2003	38.9	34.36	0.0
1-7 Oct. 2003	29.2	25.40	0.0
8-14 Oct. 2003	22.7	19.39	0.0
15-21 Oct. 2003	31.4	23.02	0.0
22-28 Oct. 2003	32.4	27.64	0.0
29 Oct.-4 Nov. 2003	35.1	27.66	0.0
5-11 Nov. 2003	13.0	11.54	3.1
12-18 Nov. 2003	15.1	13.92	0.0
19-25 Nov. 2003	13.0	11.20	16.8
26 Nov.-2 Dec. 2003	16.2	15.15	0.0
3-9 Dec. 2003	16.2	14.46	0.0
10-16 Dec. 2003	16.2	14.32	0.0
17-23 Dec. 2003	11.4	9.89	0.2
24-30 Dec. 2003	14.6	13.43	1.0
31 Dec. 2003-6 Jan. 2004	18.4	9.22	10.3
7-13 Jan. 2004	13.0	11.46	10.2
14-20 Jan. 2004	19.5	16.35	0.0
21-27 Jan. 2004	13.0	12.41	0.3
28 Jan.- 3 Feb. 2004	19.5	15.54	0.3
4-10 Feb. 2004	10.8	14.89	10.7
11-17 Feb. 2004	34.6	24.47	0.0
18-24 Feb. 2004	0.0	19.95	0.0
25 Feb.-2 Mar. 2004	2.7	8.14	43.9
3-9 Mar. 2004	11.9	15.14	50.2
10-16 Mar. 2004	32.4	29.09	0.2
17-23 Mar. 2004	34.1	30.56	0.0
24-30 Mar. 2004	32.4	27.54	0.6
31 Mar.-6 Apr. 2004	32.4	27.45	0.0
7-13 Apr. 2004	19.5	26.33	11.9

continued on next page…

[z] Actual amount of irrigation applied in a given week may differ from 110% ET_o in order to maintain representative turfgrass and due to limitations of the irrigation clock which require cycled run times to be rounded to the nearest whole minute. The calculations to determine the amount of irrigation each week are based on the previous 7 d cumulative ET_o, obtained from an on-site CIMIS station.

Table 24b *(continued)*. Weather and other information used to determine the weekly irrigation amount in Riverside, Calif., from 2 July 2003 to 12 Oct. 2004. Irrigation protocol = 110% ET_o.

Week	Irrigation applied[z]	Previous 7 d ET_o	Previous 7 d rainfall
	---------- *mm* ----------		
14-20 Apr. 2004	34.1	32.74	0.0
21-27 Apr. 2004	30.8	30.34	12.4
28 Apr.-4 May 2004	51.9	45.93	0.0
5-11 May 2004	51.9	48.79	0.0
12-18 May 2004	44.7	45.35	0.0
19-25 May 2004	60.0	41.09	0.0
26 May-1 June 2004	38.9	33.97	0.0
2-8 June 2004	38.9	36.87	0.0
9-15 June 2004	43.8	38.79	0.0
16-22 June 2004	54.6	40.4	0.0
23-29 June 2004	39.5	32.87	0.0
30 June-6 July 2004	49.2	40.97	0.0
7-13 July 2004	43.8	37.88	0.0
14-20 July 2004	51.9	39.88	0.0
21-27 July 2004	64.9	47.41	0.0
28 July-3 Aug. 2004	71.9	46.66	0.0
4-10 Aug. 2004	43.8	40.28	0.0
11-17 Aug. 2004	60.0	46	0.0
18-24 Aug. 2004	43.8	39.78	0.0
25-31 Aug. 2004	38.9	33.65	0.0
1-7 Sept. 2004	43.8	37.81	0.0
8-14 Sept. 2004	48.6	42.82	0.0
15-21 Sept. 2004	38.9	34.08	0.0
22-28 Sept. 2004	34.1	31.27	0.0
29 Sept.-5 Oct. 2004	38.9	35.02	0.0
6-12 Oct. 2004	25.9	23.57	0.0
Total	2377.9	2032.42	175.4

[z] Actual amount of irrigation applied in a given week may differ from 110% ET_o in order to maintain representative turfgrass and due to limitations of the irrigation clock which require cycled run times to be rounded to the nearest whole minute. The calculations to determine the amount of irrigation each week are based on the previous 7 d cumulative ET_o, obtained from an on-site CIMIS station.

Note: (Total irrigation applied / total ET_o) x 100 = 117%.

Table 25. The distribution uniformity (DU) and application rate of the irrigation system as determined by catch-can tests.

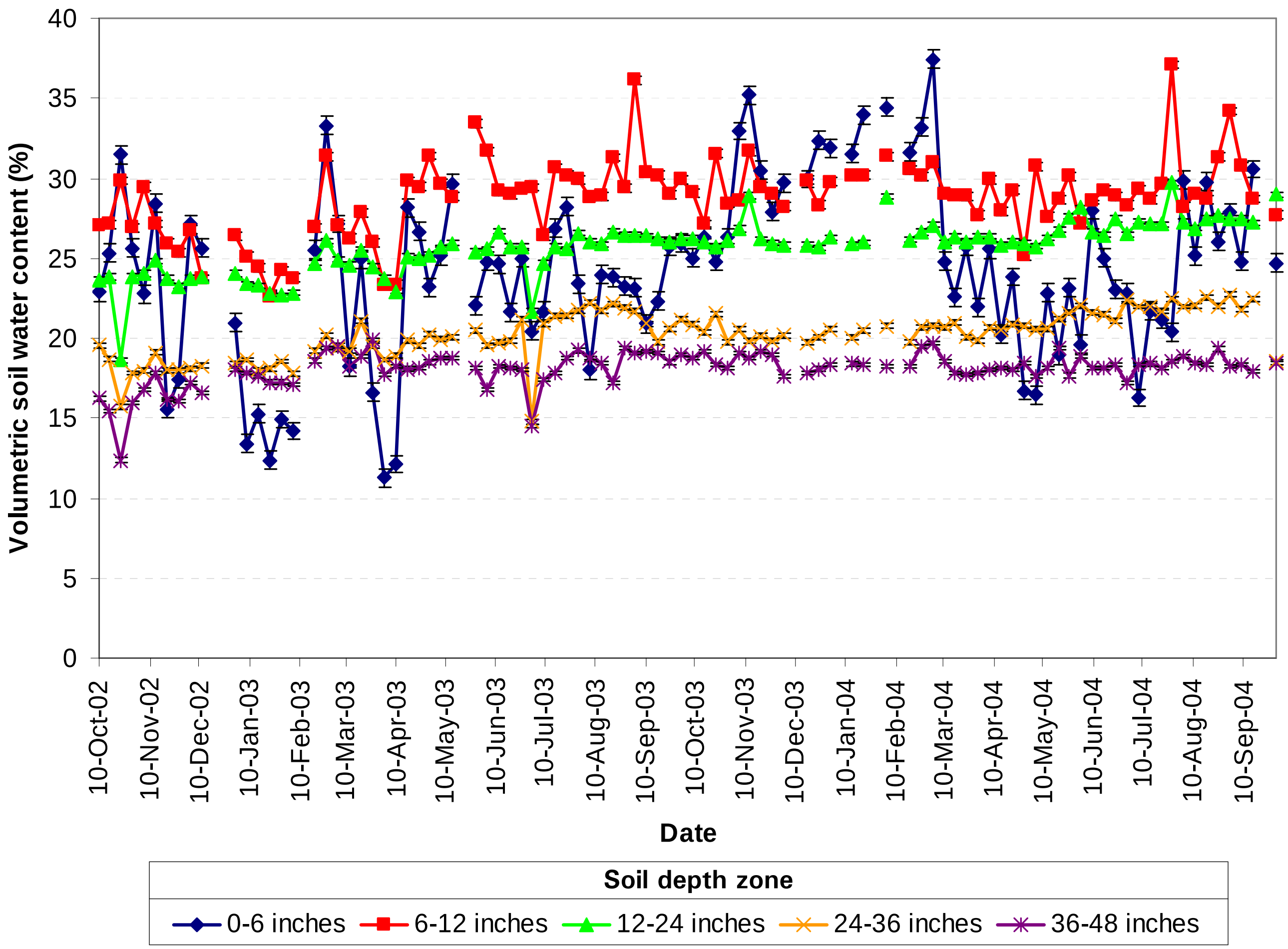
Date of catch-can test	DU (%)	Application rate Inches/h	mm/h
9 Apr. 2002[z]	76	1.2	29.9
10 Apr. 2002[z]	69	1.3	31.8
12 Apr. 2002[y]	69	1.2	31.7
12 June 2002[y]	77	1.1	28.9
14 June 2002[y]	75	1.1	28.6
20 June 2002[y]	76	1.3	32.2
3 Jan. 2003[y]	83	1.3	32.8

[z] Catch-can test conducted on entire plot prior to demarcation of research plots. Approximately 66 cans used for this test at a spacing of approximately 6 ft. Irrigation operating pressure was 55 psi. Irrigation system consisted of Rainbird Falcon part-circle rotary sprinklers with four 90° heads equipped with #10 nozzles and two 180° heads equipped with #16 nozzles. Run time for can test was 20 min.

[y] Catch-can test conducted on research area of plots only. A single can was placed in the center of each plot (including null plots), for a total of 60 cans. Irrigation operating pressure was 55 psi. Irrigation system consisted of Rainbird Falcon part-circle rotary sprinklers with four 90° heads equipped with #8 nozzles and two 180° heads equipped with #16 nozzles. Run time for can test was 10 to 15 min.

Note: Distribution uniformity is the ratio of the average low-quarter depth of irrigation to the average depth of irrigation for the whole field, expressed as a percent. Calculations of DU for the research plot were made via Turfimp© (version 1.04, Apr. 1993), a program developed by biometeorologist Richard Snyder (UC Davis).

Figure 21. Volumetric soil water content at five depth zones measured by time domain reflectometry (TDR) from 10 Oct. 2002 to 5 Oct. 2004.



Note: Data are the average of measurements from TDR probes installed in three to four separate null plots. Bars represent range of standard error of the mean.

Table 26.1. Weekly air and soil temperatures collected from the UCR Turfgrass Research Facility from Oct. 2002 to July 2003.

Week	Air temperature[z]			Average soil temperature[y]
	Maximum	Minimum	Average	
	°F			
6-12 Oct. 2002	84.6	57.0	69.1	67.5
13-19 Oct. 2002	72.0	52.3	60.4	65.9
20-26 Oct. 2002	66.5	52.3	58.0	64.3
27 Oct.-2 Nov. 2002	68.0	49.9	57.7	62.8
3-9 Nov. 2002	72.9	48.4	58.1	59.1
10-16 Nov. 2002	78.0	50.7	62.3	59.3
17-23 Nov. 2002	80.4	51.2	64.4	56.7
24-30 Nov. 2002	69.3	50.7	59.9	54.7
1-8 Dec. 2002	68.8	43.8	55.3	53.7
8-14 Dec. 2002	68.1	43.3	54.2	52.0
15-21 Dec. 2002	58.7	43.7	50.2	51.5
22-28 Dec.2002	61.8	38.2	49.1	47.6
29 Dec. 2002-4 Jan. 2003	68.5	42.5	54.8	49.2
5-11 Jan. 2003	69.5	50.8	60.4	52.3
12-18 Jan. 2003	77.0	45.6	59.5	51.7
19-25 Jan. 2003	72.8	47.7	57.6	53.1
26 Jan.-1 Feb. 2003	80.8	48.9	60.3	54.7
2-8 Feb. 2003	65.7	41.7	54.1	50.6
9-15 Feb. 2003	63.8	47.8	54.9	52.5
16-22 Feb. 2003	67.0	46.3	55.8	55.8
23 Feb.-1 Mar. 2003	58.6	47.1	52.1	54.9
2-8 Mar. 2003	64.3	41.1	52.7	54.2
9-15 Mar. 2003	72.9	49.4	59.9	58.8
16-22 Mar. 2003	68.7	45.5	56.6	58.1
23-29 Mar. 2003	73.9	50.0	62.6	60.3
30 Mar.-5 Apr. 2003	70.6	45.0	57.9	59.9
6-12 Apr. 2003	76.0	48.4	62.0	61.8
13-19 Apr. 2003	64.9	44.5	55.2	61.5
20-26 Apr. 2003	67.6	48.7	57.1	62.8
27 Apr.-3 May 2003	67.8	46.1	56.6	63.9
4-10 May 2003	67.3	49.0	57.2	63.9
11-17 May 2003	78.1	52.0	64.2	66.9
18-24 May 2003	83.3	54.8	55.7	71.8
25-31 May 2003	82.1	57.7	56.1	73.6
1-7 June 2003	77.4	58.3	65.0	73.6[x]
8-14 June 2003	75.1	57.4	61.8	72.4
15-21 June 2003	77.2	58.2	61.4	74.8[x]
22-28 June 2003	80.1	57.5	44.8	–[x]
29 June-5 July 2003	87.4	–	29.3	–[x]
6-12 July 2003	91.1	64.8	74.4	80.3[x]

[z] Air temperature data collected from an on-site California Irrigation Management System weather station located 160 ft from the center of the research plot. Data was reported on an hourly basis and averaged over each week. CIMIS data retrieved from http://www.cimis.water.ca.gov/.

[y] Soil temperature data collected from a Hobo H8 datalogger probe installed at the 4-inch depth within a null plot within the research plot.

[x] No data available (–) or average calculated from partial data due to equipment failure.

Table 26.2. Weekly air and soil temperatures collected from the UCR Turfgrass Research Facility from July 2003 to Apr. 2004.

Week	Air temperature[z]			Average soil temperature[y]
	Maximum	Minimum	Average	
	°F			
13-19 July 2003	94.5	67.6	79.9	79.5
20-26 July 2003	91.2	64.6	76.2	79.3
27 July-2 Aug. 2003	89.8	65.1	76.1	79.0[x]
3-9 Aug.2003	93.5	61.1	77.0	–[x]
10-16 Aug. 2003	99.2	65.2	82.6	–[x]
17-23 Aug. 2003	92.5	64.0	76.8	78.7[x]
24-30 Aug. 2003	94.2	64.2	78.8	78.7
31 Aug.-6 Sept. 2003	95.0	65.0	79.2	78.7
7-13 Sept. 2003	87.2	60.0	72.2	76.0
14-20 Sept. 2003	90.6	58.5	72.6	75.0
21-27 Sept. 2003	92.2	59.1	73.1	74.0
28 Sept.-4 Oct. 2003	81.3	57.2	66.8	72.7
5-11 Oct. 2003	82.5	58.0	67.3	71.2
12-18 Oct. 2003	91.0	57.3	72.4	70.3
19-25 Oct. 2003	96.2	60.3	78.2	69.2
26 Oct.-1 Nov. 2003	76.3	53.3	64.1	64.0
2-8 Nov. 2003	66.3	43.3	55.2	59.6
9-15 Nov. 2003	66.6	49.6	57.6	59.9
16-22 Nov. 2003	68.3	46.0	56.5	57.8
23-29 Nov. 2003	67.9	41.8	53.9	53.1
30 Nov.-6 Dec. 2003	73.2	42.3	57.4	52.6
7-13 Dec. 2003	62.4	41.4	52.5	52.4
14-20 Dec. 2003	68.0	41.5	53.8	48.6
21-27 Dec. 2003	61.1	41.3	51.1	50.4
28 Dec. 2003-3 Jan. 2004	59.4	37.6	48.1	47.4
4-10 Jan. 2004	69.5	39.4	54.7	47.2
11-17 Jan. 2004	73.5	43.7	58.1	50.1
18-24 Jan. 2004	62.8	41.1	53.1	49.7
25-31 Jan. 2004	63.9	43.0	52.6	50.9
1-7 Feb. 2004	62.5	38.5	52.4	50.4
8-14 Feb. 2004	64.7	38.7	53.0	47.5
15-21 Feb. 2004	62.7	43.0	51.6	51.0
22-28 Feb. 2004	57.4	42.0	49.8	53.4
29 Feb.-6 Mar. 2004	63.6	43.4	52.8	54.7
7-13 Mar. 2004	80.5	53.1	66.7	60.1
14-20 Mar. 2004	81.9	49.5	63.8	61.8[x]
21-27 Mar. 2004	71.5	50.4	58.8	64.6[x]
28 Mar.-3 Apr. 2004	77.2[x]	49.4[x]	63.1[x]	–[x]
4-10 Apr. 2004	72.0[x]	42.7[x]	62.7[x]	–[x]
11-17 Apr. 2004	73.7	49.1	60.8	–[x]
18-24 Apr. 2004	75.3	48.8	61.6	–[x]

[z] Air temperature data collected from an on-site California Irrigation Management System weather station located 160 ft from the center of the research plot. Data was reported on an hourly basis and averaged over each week. CIMIS data retrieved from http://www.cimis.water.ca.gov/.

[y] Soil temperature data collected from a Hobo H8 datalogger probe installed at the 4-inch depth within a null plot within the research plot.

[x] No data available (–) or calculated from partial data due to equipment failure.

Table 26.3. Weekly air and soil temperatures collected from the UCR Turfgrass Research Facility from Apr. 2004 to Oct. 2004.

Week	Air temperature[z]			Average soil temperature[y]
	Maximum	Minimum	Average	
	---------- °F ----------			
25 Apr.-1 May 2004	88.2	57.2	73.1	–[x]
2-7 May 2004	91.6	58.6	75.9	–[x]
9-15 May 2004	82.2	55.2	67.9	–[x]
16-22 May 2004	75.0	56.0	63.9	–[x]
23-29 May 2004	71.9	55.4	62.5	–[x]
30 May-5 June 2004	90.5	57.9	74.5	–[x]
6-12 June 2004	78.1	56.8	65.9	–[x]
13-19 June 2004	81.0	58.5	67.4	75.5[x]
20-26 June 2004	86.3	58.9	69.7	75.9
27 June-3 July 2004	80.3	57.7	66.8	75.7
4-10 July 2004	87.4	58.8	70.6	76.3
11-17 July 2004	96.5	65.9	81.1	78.0
18-24 July 2004	94.4	63.6	78.1	78.9
25-31 July 2004	92.4	60.2	74.5	78.0
1-7 Aug. 2004	88.8	60.4	73.0	77.2
8-14 Aug. 2004	94.8	65.9	79.3	78.9
15-21 Aug. 2004	87.5	62.0	72.4	78.2
22-28 Aug. 2004	84.7	57.8	69.3	76.0
29 Aug.-4 Sept. 2004	94.5	60.3	76.3	76.5
5-11 Sept. 2004	97.9	64.7	80.4	76.4
12-18 Sept. 2004	85.1	62.0	71.7	76.5
19-25 Sept. 2004	86.4	56.9	71.4	71.4
26 Sept.-2 Oct. 2004	81.1	57.1	67.1	71.0
3-9 Oct. 2004	86.9	55.5	70.5	70.2
10-16 Oct. 2004	81.7	55.0	66.1	68.8[x]

[z] Air temperature data collected from an on-site California Irrigation Management System weather station located 160 ft from the center of the research plot. Data was reported on an hourly basis and averaged over each week. CIMIS data retrieved from http://www.cimis.water.ca.gov/.

[y] Soil temperature data collected from a Hobo H8 datalogger probe installed at the 4-inch depth within a null plot within the research plot.

[x] No data available (–) or calculated from partial data due to equipment failure.

Table 27. Analyses of soil salinity/alkalinity/toxicity, fertility and textural characteristics from samples taken at the 0- to 4-inch depth rootzone each December from 2001 to 2003.

	Sample date		
	12 Dec. 2001	16 Dec. 2002	24 Dec. 2003
Soil salinity/alkalinity/toxicity[z]			
pH	6.6	7.4	7.1
Soluble Ca (ppm)	429	162	186
Soluble K (ppm)	40	32	32
Soluble Mg (ppm)	90	41	40
Soluble Na (ppm)	154	30	131
SAR	2	1	2
ESP (%)	1	<1	2
CO_3 (ppm)	<3	<3	<3
HCO_3 (ppm)	24	116	165
CEC (meq/100 g)	12.9	18.1	10.3
Soil fertility[z]			
Extractable Fe (ppm)	32	17	25
Olsen-P (ppm)	56	42	46
Exchangeable K (ppm)	166	171	186
Exchangeable Ca (ppm)	1182	1383	1303
Exchangeable Mg (ppm)	170	207	195
Exchangeable Na (ppm)	176	100	90
TKN (%)	0.073	0.117	0.086
Soil textural characteristics[z]			
OM (%)	0.93	1.80	1.30
Sand (%)	49[y]	66	61
Silt (%)	30[y]	25	28
Clay (%)	11[y]	9	11

[z]Analyses conducted according to relevant DANR analytical methodologies.
[y]Based on a second soil test taken on 15 Apr. 2002.

Table 28. Root mass density at five depths (0 to 12, 12 to 24, 24 to 36, 36 to 48, and 48 to 60 inches) below the soil-thatch layer (approximately 0.6 inches below the surface) as determined by samples taken 12 Dec. 2001 on the CDFA-FREP plot that is on a mature stand of 'Marathon III' tall fescue (*Festuca arundinacea*) in Riverside, Calif., that was seeded 3 Apr. 1996.

Section	Root mass density[z]			
	Mean	Minimum	Maximum	Standard error
	---------- *g/110 cm³* ----------			
0 to 12 inches	0.0146	0.0056	0.0268	0.0028
12 to 24 inches	0.0023	0.0009	0.0046	0.0005
24 to 36 inches	0.0006	0.0002	0.0009	0.0001
36 to 48 inches	0.0000	0.0000	0.0000	0.0000
48 to 60 inches	0.0000	0.0000	0.0002	0.0000

[z] Seven 60-inch deep cores were taken with a King Tube (0.84-inch i.d.) and divided into five 12-inch sections. The average root mass volume was then calculated based on each 12-inch section of each core having a volume of 110 cm^3.

Table 29. Soil texture and water release information of the Hanford fine sandy loam taken from the UCR Turfgrass Research Facility.

	Soil texture										Soil water content at applied pressures											
	Sand		Silt		Clay		Organic matter		Bulk density		0 KPa		−5 KPa		−10 KPa		−50 KPa		−100 KPa		−500 KPa	
Soil depth	Avg	SE	Avg	SE	Avg	SE	Avg	SE	Avg	SE	Avg	SE	Avg	SE	Avg	SE	Avg	SE	Avg	SE	Avg	SE
---- *cm* ----	% *w/w*								---- $g \cdot cm^{-3}$ ----		% *v/v*											
0 to 15	70.5	0.50	19.8	0.25	9.8	0.25	0.6	0.08	1.78	0.06	30.0	1.78	21.4	0.45	20.3	0.58	19.2	0.77	17.8	0.79	15.1	1.18
15 to 30	70.3	0.25	19.5	0.50	10.3	0.63	0.4	0.03	1.75	0.05	28.9	0.70	21.5	0.45	20.4	0.38	19.7	0.48	18.2	0.55	15.6	0.99
30 to 60	69.3	1.55	19.3	0.95	11.5	0.64	0.2	0.02	1.78	0.02	29.8	1.10	22.0	0.46	21.5	0.36	20.8	0.37	19.8	0.29	16.5	0.42
60 to 90	77.3	2.14	14.3	1.49	8.5	0.64	0.1	0.03	1.67	0.09	31.6	3.70	20.6	4.69	19.3	4.58	17.9	4.53	16.7	4.63	13.7	4.79
90 to 120	82.8	2.87	9.8	2.43	7.5	0.50	0.1	0.02	1.60	0.01	31.1	1.55	14.7	2.42	12.7	2.55	11.2	2.51	10.5	2.66	7.7	2.30
0 to 120	74.0	1.39	16.5	1.05	9.5	0.39	0.3	0.05	1.72	0.03												

CHAPTER 7:
DATA TABLES AND FIGURES AND RELATED INFORMATION –UC DAVIS

Table 30. The effect of N-fertility source and rate on visual turfgrass quality of tall fescue from Jan. to Dec. 2004 (1 to 9 scale, with 1 = worst, 5 = minimally acceptable, and 9 = best tall fescue).

Treatment		13 Jan. 2004	16 Apr. 2004	21 May 2004	11 June 2004	9 July 2004	15 Dec. 2004	11 Mar. 2005	18 Mar. 2005	15 Apr. 2005	29 Apr. 2005
ANOVA, RCB design, 13 treatments											
Source[z]	Rate[y]										
Ammonium nitrate	8	5.13	6.38	5.25	5.75	6.00	5.25	5.9	5.6	6.3	5.4
Milorganite	8	5.13	6.25	5.50	5.75	5.88	5.50	5.6	5.5	6.6	5.5
Nutralene	8	5.00	6.13	5.13	5.63	6.00	5.38	5.6	5.4	6.3	5.4
Polyon	8	4.50	6.13	6.00	5.75	5.88	5.00	5.5	5.5	7.0	6.3
Ammonium nitrate	6	5.13	6.00	5.25	5.88	6.00	5.63	5.9	5.5	6.4	5.3
Milorganite	6	5.13	5.88	5.25	5.75	5.88	5.13	5.6	5.4	6.9	5.4
Nutralene	6	5.00	6.00	5.25	5.50	5.63	5.13	5.8	5.4	6.4	5.1
Polyon	6	4.50	5.88	5.75	5.88	5.88	5.00	5.5	5.1	6.6	6.0
Ammonium nitrate	4	5.13	5.63	5.00	5.50	6.00	5.25	5.6	5.1	6.3	5.3
Milorganite	4	4.75	5.75	5.25	5.63	5.88	5.00	5.5	5.4	6.3	5.1
Nutralene	4	4.75	5.75	5.13	5.50	5.88	4.88	5.6	5.3	6.1	5.1
Polyon	4	4.50	5.75	5.25	5.88	6.00	4.63	5.5	4.9	6.1	5.5
Check	0	4.38	5.13	5.00	5.63	5.88	4.13	5.4	4.4	5.0	4.8
LSD, $P = 0.05$[x]		0.45	0.36	0.43	NS	NS	0.39	0.4	0.5	0.5	0.3
Randomized complete block design effects (*P*)											
Treatment		0.0017	<0.0001	0.0010	0.2015	0.3374	<0.0001	0.2063	0.0003	<0.0001	<0.0001
ANOVA, 4 × 3 factorial design, 12 treatments											
Source[z]											
Ammonium nitrate		5.13	6.00	5.17	5.71	6.00	5.38	5.8	5.4	6.3	5.3
Milorganite		5.00	5.96	5.33	5.71	5.88	5.21	5.6	5.4	6.6	5.3
Nutralene		4.92	5.96	5.17	5.54	5.83	5.13	5.7	5.3	6.3	5.2
Polyon		4.50	5.92	5.67	5.83	5.92	4.88	5.5	5.2	6.6	5.9
LSD, $P = 0.05$[x]		0.25	NS	0.26	0.20	NS	0.23	0.2	0.3	0.2	0.2
Rate[y]											
8		4.94	6.22	5.47	5.72	5.94	5.28	5.7	5.5	6.5	5.6
6		4.94	5.94	5.38	5.75	5.84	5.22	5.7	5.3	6.6	5.4
4		4.78	5.72	5.16	5.63	5.94	4.94	5.6	5.2	6.2	5.3
LSD, $P = 0.05$[x]		NS	0.18	0.22	NS	NS	0.20	0.2	0.2	0.2	0.2
Factorial design effects (*P*)											
Source (S)		0.0001	0.8754	0.0009	0.0437	0.1713	0.0011	0.0241	0.1922	0.0087	<0.0001
Rate (R)		0.2584	<0.0001	0.0211	0.3174	0.2685	0.0029	0.2851	0.0154	0.0014	0.0002
S x R		0.7980	0.6830	0.3001	0.5605	0.3480	0.1875	0.8941	0.5892	0.0725	0.1182

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 15 Nov. 2003 and 15 Mar., 18 May, 16 Aug., and 2 Nov. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P = 0.05$.

Table 31. The effect of N-fertility source and rate on visual turfgrass color of tall fescue from Jan. to Dec. 2004 (1 to 9 scale, with 1=brown, 5=minimally acceptable, and 9=darkest green tall fescue).

Treatment		13 Jan. 2004	16 Apr. 2004	21 May 2004	11 June 2004	9 July 2004	15 Dec. 2004
ANOVA, RCB design, 13 treatments							
Source[z]	Rate[y]						
Ammonium nitrate	8	5.75	6.38	5.25	5.75	6.00	5.25
Milorganite	8	5.75	6.25	5.50	5.75	5.88	5.50
Nutralene	8	5.50	6.13	5.13	5.63	6.00	5.38
Polyon	8	5.13	6.13	6.00	5.88	5.88	5.00
Ammonium nitrate	6	5.75	6.00	5.25	5.88	6.00	5.63
Milorganite	6	5.75	5.88	5.25	5.75	5.88	5.13
Nutralene	6	5.38	6.00	5.25	5.50	5.63	5.13
Polyon	6	4.88	5.88	5.75	5.88	5.88	5.00
Ammonium nitrate	4	5.63	5.63	5.00	5.50	6.00	5.25
Milorganite	4	5.13	5.75	5.25	5.63	5.88	5.00
Nutralene	4	5.38	5.75	5.00	5.50	5.88	4.88
Polyon	4	4.75	5.75	5.25	5.88	6.00	4.63
Check	0	4.50	5.13	4.88	5.63	5.88	4.13
LSD, $P=0.05$[x]		0.65	0.36	0.43	NS	NS	0.39
Randomized complete block design effects *(P)*							
Treatment		0.0020	<0.0001	0.0005	0.1283	0.3374	<0.0001
ANOVA, 4×3 factorial design, 12 treatments							
Source[z]							
Ammonium nitrate		5.71	6.00	5.17	5.71	6.00	5.38
Milorganite		5.54	5.96	5.33	5.71	5.88	5.21
Nutralene		5.42	5.96	5.13	5.54	5.83	5.13
Polyon		4.92	5.92	5.67	5.88	5.92	4.88
LSD, $P=0.05$[x]		0.38	NS	0.26	0.20	NS	0.23
Rate[y]							
8		5.53	6.22	5.47	5.75	5.94	5.28
6		5.44	5.94	5.38	5.75	5.84	5.22
4		5.22	5.72	5.13	5.63	5.94	4.94
LSD, $P=0.05$[x]		NS	0.18	0.23	NS	NS	0.20
Factorial design effects *(P)*							
Source (S)		0.0011	0.8754	0.0007	0.0156	0.1713	0.0011
Rate (R)		0.1523	<0.0001	0.0116	0.2380	0.2685	0.0029
S x R		0.8188	0.6830	0.4186	0.7090	0.3480	0.1875

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 15 Nov. 2003 and 15 Mar., 18 May, 16 Aug., and 2 Nov. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Table 32.1. The effect of N-fertility source and rate on clipping yield (dry weight) of tall fescue from 31 Dec. 2003 to 22 Jan. 2004.

Treatment		2-week growth period (31 Dec. 2003 to 22 Jan. 2004)[z]		
		Sample date		2-week total yield
		6 Jan.	22 Jan.	
		---------- $g \cdot m^{-2}$ *per 7 d* ----------		$g \cdot m^{-2}$ *per 14 d*
		ANOVA, RCB design, 13 treatments		
Source[y]	Rate[x]			
Ammonium nitrate	8	5.04	5.33	10.35
Milorganite	8	4.13	5.04	9.17
Nutralene	8	4.00	4.85	8.85
Polyon	8	2.92	3.88	6.80
Ammonium nitrate	6	4.60	5.24	9.84
Milorganite	6	3.90	3.98	7.88
Nutralene	6	3.61	4.61	8.22
Polyon	6	2.83	2.94	5.77
Ammonium nitrate	4	4.70	4.80	9.50
Milorganite	4	4.11	3.97	8.08
Nutralene	4	3.44	3.90	7.34
Polyon	4	4.09	3.17	7.26
Check	0	3.38	3.99	7.37
LSD, $P = 0.05$[w]		NS	1.68	NS
Randomized complete block design effects (*P*)				
Treatment		0.0741	0.0089	0.1836
		ANOVA, 4 × 3 factorial design, 12 treatments		
Source[y]				
Ammonium nitrate		4.78	5.12	9.90
Milorganite		4.05	4.33	8.38
Nutralene		3.69	4.45	8.14
Polyon		3.28	3.33	6.61
LSD, $P = 0.05$[w]		1.09	0.96	1.80
Rate[x]				
8		4.02	4.77	8.79
6		3.73	4.19	7.92
4		4.09	3.96	8.05
LSD, $P = 0.05$[w]		NS	NS	NS
Factorial design effects (*P*)				
Source (S)		0.0537	0.0059	0.0080
Rate (R)		0.7225	0.1369	0.4768
S x R		0.8782	0.9605	0.9488

[z] Clipping yields taken 7 weeks after fertilizer application.

[y] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[x] Annual rates as lb N/1000 ft^2 per year. Applied 15 Nov. 2003 and 15 Mar., 18 May, 16 Aug., and 2 Nov. 2004.

[w] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P = 0.05$.

Table 32.2. The effect of N-fertility source and rate on clipping yield (dry weight) of tall fescue from 15 Apr. to 12 May 2004.

Treatment		4-week growth period (15 Apr. to 12 May 2004)[z]				
		Sample date				4-week total yield
		21 Apr.	28 Apr.	5 May	12 May	
		---------- $g \cdot m^{-2}$ per 7 d ----------				$g \cdot m^{-2}$ per 28 d
ANOVA, RCB design, 13 treatments						
Source[y]	Rate[x]					
Ammonium nitrate	8	39.96	37.54	19.30	13.91	110.71
Milorganite	8	29.24	29.80	17.10	11.33	87.44
Nutralene	8	36.64	28.27	20.51	13.80	99.22
Polyon	8	33.71	36.01	25.80	18.16	113.68
Ammonium nitrate	6	38.61	35.84	20.43	16.78	111.66
Milorganite	6	31.29	32.13	14.97	10.47	88.86
Nutralene	6	35.53	26.15	18.77	13.19	93.64
Polyon	6	27.73	26.47	18.29	10.84	83.33
Ammonium nitrate	4	34.36	27.77	17.16	11.89	91.18
Milorganite	4	26.89	22.36	16.80	11.12	77.17
Nutralene	4	28.59	26.32	16.30	13.09	84.30
Polyon	4	19.38	23.93	13.01	11.95	68.27
Check	0	18.21	18.92	9.54	8.20	54.87
LSD, $P=0.05$[w]		6.40	7.49	4.65	4.95	15.94
Randomized complete block design effects (*P*)						
Treatment		<0.0001	0.0002	<0.0001	0.0240	<0.0001
ANOVA, 4 × 3 factorial design, 12 treatments						
Source[y]						
Ammonium nitrate		37.64	33.72	18.96	14.19	104.51
Milorganite		29.14	28.10	16.28	10.97	84.49
Nutralene		33.59	26.91	18.53	13.36	92.39
Polyon		26.94	28.80	19.03	13.65	88.42
LSD, $P=0.05$[w]		3.65	4.34	NS	NS	9.08
Rate[x]						
8		34.89	32.91	20.66	14.30	102.76
6		33.29	30.15	18.11	12.82	94.37
4		27.30	25.09	15.82	12.01	80.22
LSD, $P=0.05$[w]		3.16	3.76	2.30	NS	7.86
Factorial design effects (*P*)						
Source (S)		<0.0001	0.0166	0.1360	0.1335	0.0006
Rate (R)		<0.0001	0.0007	0.0007	0.1871	<0.0001
S x R		0.2423	0.1818	0.0097	0.1273	0.0275

[z] Clipping yields taken 5 weeks after fertilizer application.

[y] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[x] Annual rates as lb N/1000 ft^2 per year. Applied 15 Nov. 2003 and 15 Mar., 18 May, 16 Aug., and 2 Nov. 2004.

[w] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Table 32.3. The effect of N-fertility source and rate on clipping yield (dry weight) of tall fescue from 1 to 27 July 2004.

Treatment		4-week growth period (1 to 27 July 2004)[z]				
		Sample date				4-week total yield
		7 July	14 July	20 July	27 July	
		g·m^{-2} per 7 d				*g·m^{-2} per 28 d*
ANOVA, RCB design, 13 treatments						
Source[y]	Rate[x]					
Ammonium nitrate	8	25.30	26.14	17.87	14.70	84.01
Milorganite	8	26.01	18.88	17.39	16.51	78.79
Nutralene	8	25.19	20.03	20.56	17.93	83.71
Polyon	8	31.48	19.43	22.80	17.14	90.85
Ammonium nitrate	6	19.13	15.65	16.26	14.26	65.30
Milorganite	6	23.81	17.95	19.00	14.85	75.61
Nutralene	6	20.30	14.49	15.65	15.82	66.26
Polyon	6	31.73	24.10	19.34	15.54	90.71
Ammonium nitrate	4	15.60	10.51	15.98	12.69	54.78
Milorganite	4	20.68	15.46	15.54	15.27	66.95
Nutralene	4	18.37	14.79	16.13	14.66	63.95
Polyon	4	17.20	16.26	17.01	19.55	70.02
Check	0	11.16	9.19	11.62	10.86	42.83
LSD, $P=0.05$[w]		10.15	9.59	3.42	4.33	20.70
Randomized complete block design effects (P)						
Treatment		0.0007	0.0504	<0.0001	0.0388	0.0009
ANOVA, 4 × 3 factorial design, 12 treatments						
Source[y]						
Ammonium nitrate		20.01	17.43	16.70	13.88	68.02
Milorganite		23.50	17.43	17.31	15.54	73.78
Nutralene		21.29	16.44	17.44	16.14	71.31
Polyon		26.80	19.93	19.72	17.41	83.86
LSD, $P=0.05$[w]		NS	NS	2.02	NS	NS
Rate[x]						
8		26.99	21.12	19.65	16.57	84.33
6		23.74	18.05	17.56	15.12	74.47
4		17.96	14.25	16.17	15.54	63.92
LSD, $P=0.05$[w]		5.19	4.93	1.75	NS	10.51
Factorial design effects (P)						
Source (S)		0.1274	0.6407	0.0251	0.0640	0.0668
Rate (R)		0.0044	0.0272	0.0012	0.4074	0.0017
S x R		0.6172	0.3002	0.1544	0.5128	0.7074

[z] Clipping yields taken 7 weeks after each fertilizer application.

[y] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[x] Annual rates as lb N/1000 ft^2 per year. Applied 15 Nov. 2003 and 15 Mar., 18 May, 16 Aug., and 2 Nov. 2004.

[w] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Table 32.4. The effect of N-fertility source and rate on clipping yield (dry weight) of tall fescue from 30 Mar. to 26 Apr. 2005.

Treatment		4-week growth period (30 Mar. to 26 Apr. 2005)[z]				
		Sample date				4-week total yield
		5 Apr.	12 Apr.	19 Apr.	26 Apr.	
		$g \cdot m^{-2}$ per 7 d				$g \cdot m^{-2}$ per 28 d
ANOVA, RCB design, 13 treatments						
Source[y]	Rate[x]					
Ammonium nitrate	8	16.9	15.4	14.5	12.5	59.4
Milorganite	8	21.2	18.4	15.9	14.8	70.3
Nutralene	8	20.6	17.0	16.7	15.1	69.4
Polyon	8	23.5	16.9	21.4	16.3	78.1
Ammonium nitrate	6	19.3	15.5	15.4	10.2	60.4
Milorganite	6	17.8	15.7	16.4	13.7	63.6
Nutralene	6	17.3	12.1	13.5	10.4	53.2
Polyon	6	15.6	12.5	15.5	12.6	56.2
Ammonium nitrate	4	14.2	14.3	15.0	12.1	55.6
Milorganite	4	12.9	10.2	10.4	8.3	41.8
Nutralene	4	13.5	10.6	12.5	9.9	46.5
Polyon	4	13.6	12.6	15.8	12.2	54.2
Check	0	7.3	5.6	9.4	6.4	28.7
LSD, $P=0.05$[w]		4.49	3.94	3.85	3.00	10.84
Randomized complete block design effects (P)						
Treatment		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
ANOVA, 4 × 3 factorial design, 12 treatments						
Source[y]						
Ammonium nitrate		16.80	15.05	14.98	11.62	58.45
Milorganite		17.29	14.79	14.23	12.28	58.59
Nutralene		17.09	13.26	14.22	11.79	56.37
Polyon		17.56	13.98	17.58	13.69	62.82
LSD, $P=0.05$[w]		2.69	2.38	2.30	1.78	6.51
Rate[x]						
8		20.53	16.94	17.13	14.68	69.28
6		17.49	13.93	15.21	11.72	58.36
4		13.54	11.94	13.41	10.64	49.53
LSD, $P=0.05$[w]		2.33	2.06	1.99	1.54	5.64
Factorial design effects (P)						
Source (S)		0.9490	0.4214	0.0165	0.0949	0.2524
Rate (R)		<0.0001	<0.0001	0.0026	<0.0001	<0.0001
S x R		0.1171	0.1692	0.0551	0.0316	0.0125

[z] Clipping yields taken 4 weeks after each fertilizer application.

[y] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[x] Annual rates as lb N/1000 ft^2 per year. Applied 15 Mar. 2005, 3 May 2005, 16 Aug. 2005, 15 Oct. 2005.

[w] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Table 32.5. The effect of N-fertility source and rate on clipping yield (dry weight) of tall fescue from 26 May to 22 June 2005.

Treatment		4-week growth period (26 May to 22 June 2005)[z]				
		Sample date				4-week
		1 June	8 June	15 June	22 June	total yield
		g·m^-2^ per 7 d				*g·m^-2^ per 28 d*
ANOVA, RCB design, 13 treatments						
Source[y]	Rate[x]					
Ammonium nitrate	8	20.7	16.0	11.9	11.8	60.4
Milorganite	8	24.0	15.8	15.0	16.0	70.8
Nutralene	8	18.9	15.9	12.1	12.9	59.7
Polyon	8	20.1	20.2	20.4	20.8	81.4
Ammonium nitrate	6	15.3	12.4	9.6	9.7	47.1
Milorganite	6	14.2	13.0	9.7	9.9	46.8
Nutralene	6	15.5	12.3	8.0	9.9	45.7
Polyon	6	18.1	13.9	12.9	16.5	61.4
Ammonium nitrate	4	16.5	12.3	7.8	7.9	44.5
Milorganite	4	12.4	9.1	7.4	7.2	36.0
Nutralene	4	12.7	10.3	7.1	7.7	37.9
Polyon	4	15.0	12.6	9.6	11.0	48.2
Check	0	7.4	7.7	5.5	5.3	25.9
LSD, $P=0.05$[w]		4.48	4.19	4.49	3.92	12.92
Randomized complete block design effects (*P*)						
Treatment		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
ANOVA, 4 × 3 factorial design, 12 treatments						
Source[y]						
Ammonium nitrate		17.50	13.56	9.78	9.81	50.66
Milorganite		16.87	12.62	10.68	11.03	51.18
Nutralene		15.72	12.85	9.05	10.16	47.77
Polyon		17.71	15.56	14.30	16.12	63.68
LSD, $P=0.05$[w]		2.69	2.49	2.71	2.36	7.79
Rate[x]						
8		20.92	16.96	14.84	15.36	68.07
6		15.78	12.91	10.05	11.50	50.23
4		14.15	11.08	7.96	8.48	41.67
LSD, $P=0.05$[w]		2.33	2.15	2.35	2.05	6.75
Factorial design effects (*P*)						
Source (S)		0.4445	0.0862	0.0200	0.0103	0.0011
Rate (R)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
S x R		0.1494	0.7474	0.4813	<0.0001	0.4517

[z] Clipping yields taken 4 weeks after each fertilizer application.

[y] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[x] Annual rates as lb N/1000 ft^2 per year. Applied 15 Mar. 2005, 3 May 2005, 16 Aug. 2005, 15 Oct. 2005.

[w] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Table 32.6. The effect of N-fertility source and rate on clipping yield (dry weight) of tall fescue from 7 Sept. to 4 Oct. 2005.

		4-week growth period (7 Sept. to 4 Oct. 2005)[z]				
		Sample date				3-week
Treatment		13 Sept.[y]	20 Sept.	27 Sept.	4 Oct.	total yield
		g·m^{-2} per 7 d				*g·m^{-2} per 21 d*
		ANOVA, RCB design, 13 treatments				
Source[x]	Rate[w]					
Ammonium nitrate	8	–	20.1	18.5	21.1	59.7
Milorganite	8	–	26.6	22.3	23.7	72.6
Nutralene	8	–	23.7	20.1	19.9	63.7
Polyon	8	–	22.6	19.9	24.2	66.7
Ammonium nitrate	6	–	19.0	17.6	18.8	55.4
Milorganite	6	–	20.4	16.0	19.2	55.6
Nutralene	6	–	25.1	19.8	22.0	66.9
Polyon	6	–	18.3	16.5	19.4	54.3
Ammonium nitrate	4	–	20.4	17.6	20.6	58.6
Milorganite	4	–	13.8	12.1	15.5	41.4
Nutralene	4	–	15.5	14.5	15.0	45.1
Polyon	4	–	21.4	20.3	18.0	59.7
Check	0	–	13.4	10.8	11.3	35.5
LSD, $P=0.05$[v]		–	7.0	7.1	3.47	20.27
Randomized complete block design effects (P)						
Treatment		–	0.0125	0.0841	0.0822	0.0311
		ANOVA, 4 × 3 factorial design, 12 treatments				
Source[x]						
Ammonium nitrate		–	19.81	17.85	20.07	57.73
Milorganite		–	20.30	16.69	19.45	56.44
Nutralene		–	21.82	18.34	19.26	59.42
Polyon		–	20.73	18.77	20.78	60.27
LSD, $P=0.05$[v]		–	4.21	4.22	4.57	12.02
Rate[w]		–				
8		–	23.22	20.16	22.37	65.75
6		–	20.72	17.49	19.86	58.06
4		–	17.98	16.25	17.53	51.76
LSD, $P=0.05$[v]		–	3.66	3.67	3.98	10.45
Factorial design effects (P)						
Source (S)		–	0.6698	0.8066	0.9807	0.8936
Rate (R)		–	0.1130	0.3333	0.2753	0.1840
S x R		–	0.2252	0.7819	0.6740	0.5777

[z] Clipping yields taken 4 weeks after each fertilizer application.

[y] Clipping yields could not be collected due to weather conditions.

[x] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[w] Annual rates as lb N/1000 ft^2 per year. Applied 15 Mar. 2005, 3 May 2005, 16 Aug. 2005, 15 Oct. 2005.

[v] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Table 32.7. The effect of N-fertility source and rate on clipping yield (dry weight) of tall fescue from 9 Nov. to 6 Dec. 2005.

Treatment		4-week growth period (9 Nov. to 6 Dec. 2005)[z]				
		Sample date				4-week total yield
		15 Nov.	22 Nov.	29 Nov.	6 Dec.	
		$g \cdot m^{-2}$ per 7 d				$g \cdot m^{-2}$ per 28 d
ANOVA, RCB design, 13 treatments						
Source[y]	Rate[x]					
Ammonium nitrate	8	15.3	5.4	4.9	3.7	29.2
Milorganite	8	14.0	6.3	6.1	4.0	30.4
Nutralene	8	15.4	5.7	5.0	3.4	29.4
Polyon	8	15.7	6.5	4.8	4.7	31.7
Ammonium nitrate	6	16.3	5.4	4.9	3.3	30.0
Milorganite	6	14.3	5.0	4.7	3.2	27.2
Nutralene	6	15.1	6.1	4.8	2.9	28.8
Polyon	6	11.8	3.9	3.7	3.3	22.7
Ammonium nitrate	4	14.6	7.1	5.1	3.9	30.7
Milorganite	4	11.1	3.8	3.3	2.0	20.2
Nutralene	4	10.5	3.7	3.5	2.9	20.6
Polyon	4	10.1	4.3	3.7	2.5	20.6
Check	0	9.4	3.7	3.1	2.7	18.8
LSD, $P=0.05$[w]		5.31	3.29	2.21	1.70	10.65
Randomized complete block design effects (*P*)						
Treatment		0.1047	0.3982	0.2397	0.2159	0.1136
ANOVA, 4 × 3 factorial design, 12 treatments						
Source[y]						
Ammonium nitrate		15.38	5.97	4.99	3.63	29.96
Milorganite		13.35	5.13	4.81	3.16	26.46
Nutralene		13.52	5.10	4.37	3.01	26.00
Polyon		12.53	4.89	4.06	3.48	24.96
LSD, $P=0.05$[w]		3.06	1.95	1.32	1.00	6.28
Rate[x]						
8		15.08	5.97	5.22	3.97	30.25
6		14.37	5.10	4.52	3.16	27.15
4		11.62	4.78	3.93	2.87	23.20
LSD, $P=0.05$[w]		2.65	1.69	1.14	0.86	5.44
Factorial design effects (*P*)						
Source (S)		0.2941	0.6750	0.3333	0.5869	0.3775
Rate (R)		0.0672	0.4945	0.2097	0.0846	0.1089
S x R		0.6361	0.4227	0.8302	0.5450	0.5977

[z] Clipping yields taken 4 weeks after each fertilizer application.

[y] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[x] Annual rates as lb N/1000 ft^2 per year. Applied 15 Mar. 2005, 3 May 2005, 16 Aug. 2005, 15 Oct. 2005.

[w] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Figure 22. The effect of 13 treatments on NO_3^--N concentration in leachate, 5 Jan. 2004 to 18 Nov. 2005 at UC Davis.

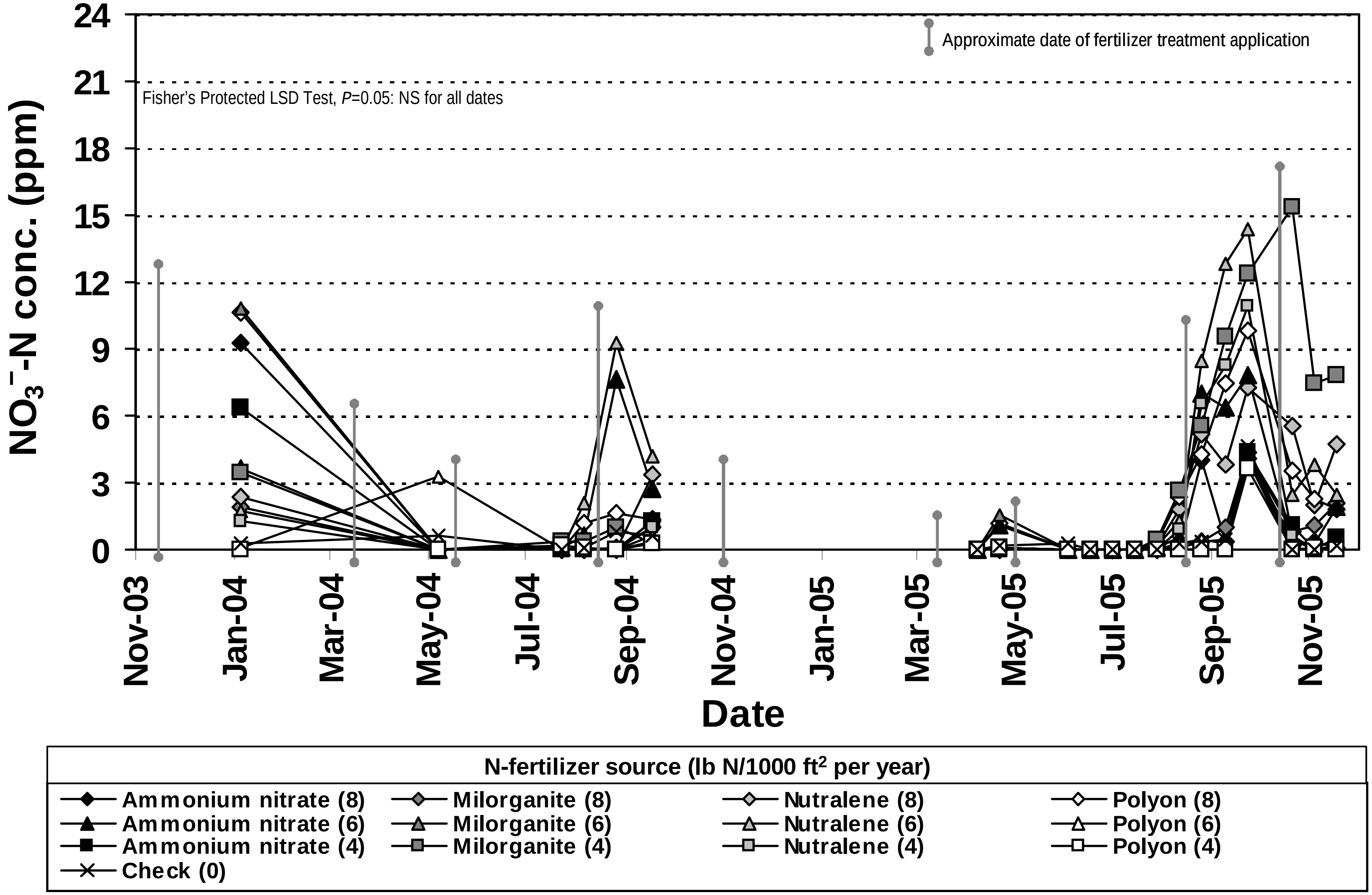


Figure 23. The effect of four N-fertilizer sources on NO_3^--N concentration in leachate, 5 Jan. 2004 to 18 Nov. 2005 at UC Davis. Means are the average of three N-fertilizer rates.

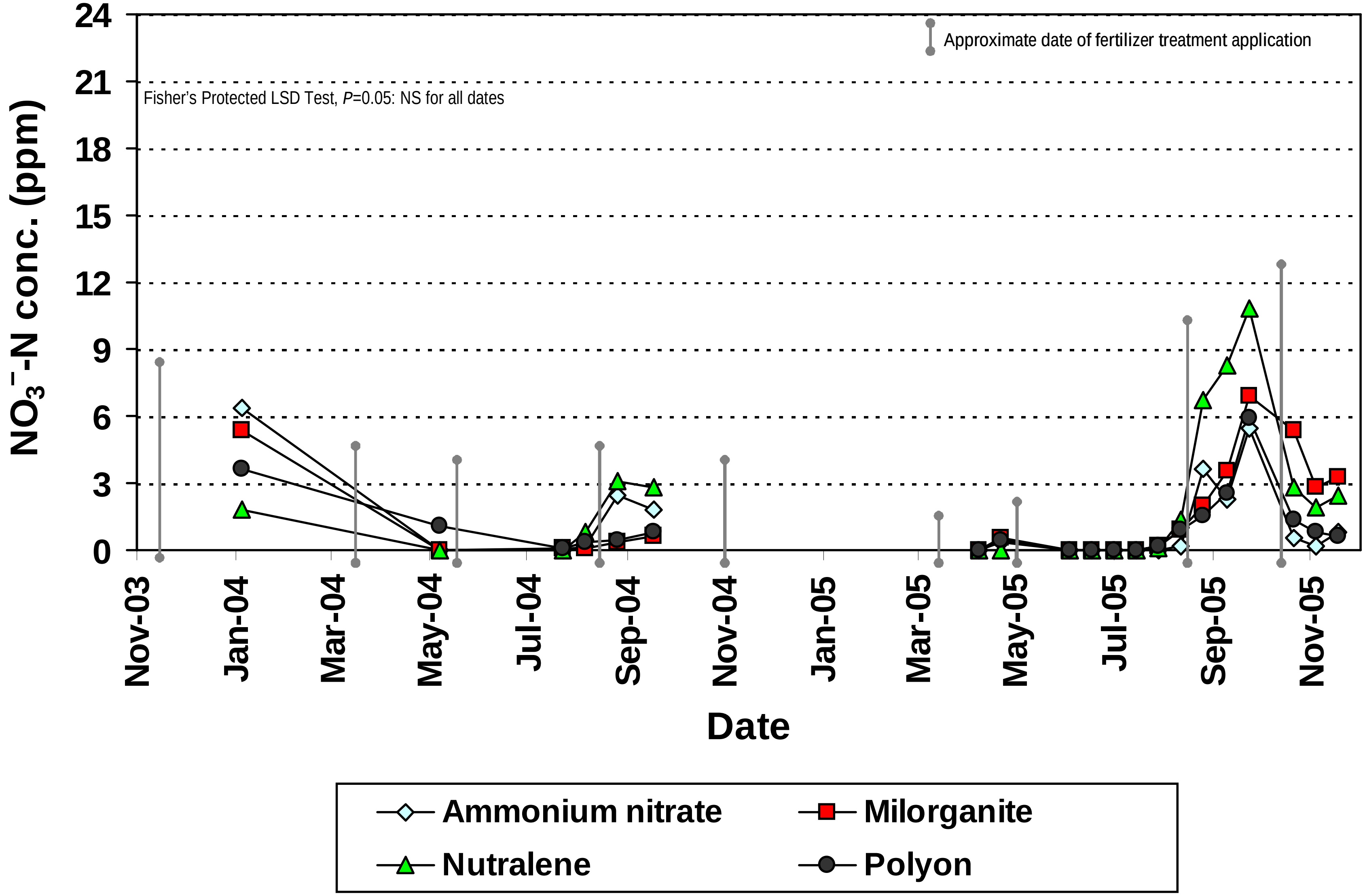


Figure 24. The effect of three N-fertilizer rates on NO_3^--N concentration in leachate, 5 Jan. 2004 to 18 Nov. 2005 at UC Davis. Means are the average of four N-fertilizer sources.

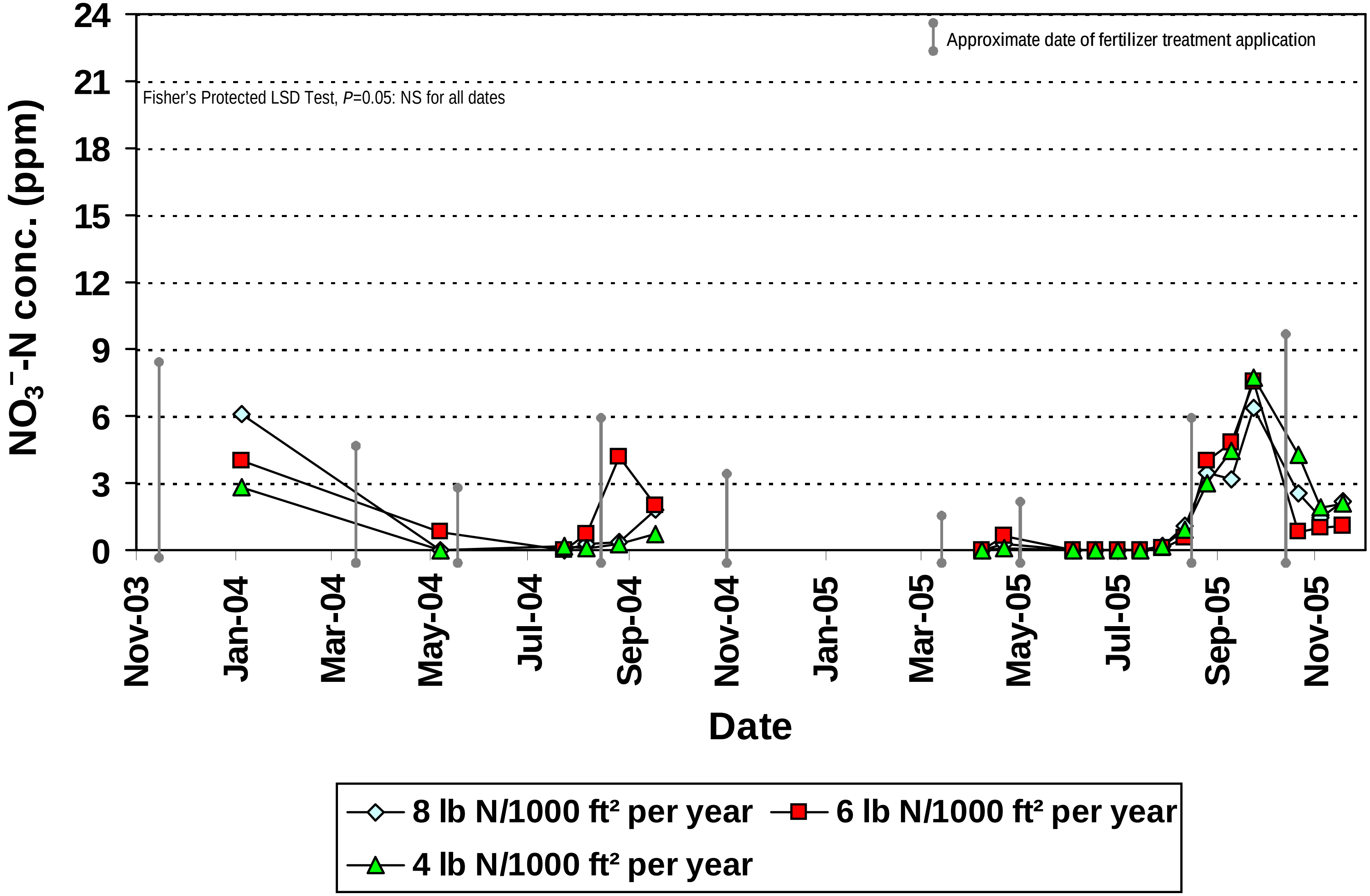


Table 33.1. The effect of N-fertility source and rate on NO_3^--N leached at the 50-cm depth from tall fescue from Jan. to Sept. 2004.

Treatment		5 Jan. 2004	7 May 2004	23 July 2004	6 Aug. 2004	26 Aug. 2004	17 Sept. 2004
		ppm					
ANOVA, RCB design, 13 treatments							
Source[z]	Rate[y]						
Ammonium nitrate	8	9.3	0.0	0.0	0.0	0.0	1.3
Milorganite	8	1.9	0.0	0.0	0.0	0.1	1.0
Nutralene	8	2.4	0.0	0.0	0.0	0.0	3.4
Polyon	8	10.6	0.0	0.0	1.2	1.6	1.4
Ammonium nitrate	6	3.6	0.0	0.1	0.6	7.6	2.7
Milorganite	6	10.8	0.0	0.0	0.0	0.0	0.4
Nutralene	6	1.7	0.0	0.0	2.1	9.3	4.2
Polyon	6	0.1	3.3	0.0	0.0	0.0	0.6
Ammonium nitrate	4	6.4	0.0	0.0	0.0	0.0	1.3
Milorganite	4	3.5	0.0	0.4	0.4	1.0	0.3
Nutralene	4	1.3	0.0	0.0	0.0	0.0	1.0
Polyon	4	0.0	0.0	0.2	0.1	0.0	0.3
Check	0	0.3	0.6	0.0	0.1	0.8	0.6
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS
Randomized complete block design effects *(P)*							
Treatment		0.5293	0.4777	0.5768	0.4777	0.4811	0.2619
ANOVA, 4 × 3 factorial design, 12 treatments							
Source[z]							
Ammonium nitrate		6.4	0.0	0.0	0.2	2.5	1.8
Milorganite		5.4	0.0	0.1	0.1	0.4	0.6
Nutralene		1.8	0.0	0.0	0.8	3.1	2.8
Polyon		3.6	1.1	0.1	0.4	0.5	0.8
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS
Rate[y]							
8		6.1	0.0	0.0	0.3	0.4	1.8
6		4.0	0.8	0.0	0.7	4.2	2.0
4		2.8	0.0	0.2	0.1	0.3	0.7
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS
Factorial design effects *(P)*							
Source (S)		0.5637	0.4114	0.6456	0.7210	0.6530	0.0737
Rate (R)		0.5622	0.3804	0.2386	0.4806	0.1724	0.2491
S x R		0.4325	0.4500	0.5778	0.2753	0.5034	0.7438

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 15 Nov. 2003 and 15 Mar., 18 May, 16 Aug., and 2 Nov. 2004.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Table 33.2. The effect of N-fertility source and rate on NO_3^--N leached at the 2.5-ft depth from tall fescue from Apr. to Nov. 2005.

Treatment		8 Apr. 2005	22 Apr. 2005	3 June 2005	17 June 2005	1 July 2005	15 July 2005	29 July 2005	12 Aug. 2005	26 Aug. 2005	9 Sept. 2005	23 Sept. 2005	21 Oct. 2005	4 Nov. 2005	18 Nov. 2005
		ppm													
ANOVA, RCB design, 13 treatments															
Source[z]	Rate[y]														
Ammonium nitrate	8	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.12	3.99	0.40	4.08	0.17	0.35	0.09
Milorganite	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.37	1.04	4.40	0.78	1.09	2.05
Nutralene	8	0.00	0.00	0.00	0.00	0.00	0.00	0.21	1.85	5.18	3.82	7.26	5.52	1.99	4.77
Polyon	8	0.00	1.18	0.00	0.00	0.00	0.00	0.36	2.33	4.29	7.43	9.78	3.59	2.31	1.86
Ammonium nitrate	6	0.00	1.07	0.00	0.00	0.00	0.00	0.05	0.52	6.99	6.35	7.79	0.36	0.27	1.88
Milorganite	6	0.00	1.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.03	0.00	0.00
Nutralene	6	0.00	0.03	0.00	0.00	0.00	0.00	0.15	1.26	8.45	12.78	14.38	2.41	3.86	2.48
Polyon	6	0.00	0.02	0.00	0.00	0.00	0.00	0.03	0.30	0.49	0.25	4.20	0.49	0.00	0.09
Ammonium nitrate	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.40	1.10	0.00	0.52
Milorganite	4	0.00	0.13	0.00	0.00	0.00	0.00	0.50	2.68	5.57	9.54	12.36	15.36	7.45	7.86
Nutralene	4	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.91	6.56	8.26	10.92	0.63	0.00	0.00
Polyon	4	0.00	0.12	0.00	0.00	0.00	0.00	0.03	0.02	0.00	0.00	3.66	0.00	0.12	0.00
Check	0	0.00	0.14	0.29	0.00	0.00	0.00	0.02	0.30	0.32	0.42	4.64	0.00	0.00	0.17
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Randomized complete block design effects (*P*)															
Treatment		.	0.1942	0.4777	.	.	.	0.3363	0.2943	0.6499	0.5249	0.4717	0.4913	0.4858	0.4315
ANOVA, 4 × 3 factorial design, 12 treatments															
Source[z]															
Ammonium nitrate		0.00	0.38	0.00	0.00	0.00	0.00	0.02	0.21	3.66	2.25	5.42	0.54	0.21	0.83
Milorganite		0.00	0.55	0.00	0.00	0.00	0.00	0.17	0.93	1.98	3.53	6.92	5.39	2.85	3.30
Nutralene		0.00	0.01	0.00	0.00	0.00	0.00	0.13	1.34	6.73	8.29	10.85	2.85	1.95	2.42
Polyon		0.00	0.44	0.00	0.00	0.00	0.00	0.14	0.88	1.59	2.56	5.88	1.36	0.81	0.65
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rate[y]															
8		0.00	0.31	0.00	0.00	0.00	0.00	0.14	1.10	3.46	3.17	6.38	2.51	1.43	2.19
6		0.00	0.66	0.00	0.00	0.00	0.00	0.06	0.52	3.98	4.85	7.59	0.82	1.03	1.11
4		0.00	0.06	0.00	0.00	0.00	0.00	0.14	0.90	3.03	4.45	7.73	4.27	1.89	2.10
LSD, $P=0.05$[x]		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Factorial design effects (*P*)															
Source (S)		.	0.5148	.	.	.	.	0.6276	0.4695	0.3139	0.3819	0.2929	0.5657	0.5051	0.4625
Rate (R)		.	0.1993	.	.	.	.	0.6570	0.6362	0.9332	0.8716	0.8409	0.5536	0.8680	0.7738
S x R		.	0.1461	.	.	.	.	0.1544	0.1619	0.6186	0.3777	0.3629	0.3239	0.2801	0.2651

[z]Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y]Annual rates as lb N/1000 ft^2 per year. Applied 15 Mar. 2005, 3 May 2005, 16 Aug. 2005, 15 Oct. 2005.

[x]Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Table 34. Percent coverage of plots in each treatment affected by *Rhizoctonia* brown patch on three dates during the summer of 2004.

Treatment		15 July 2004	27 July 2004	19 Aug. 2004
		------ *% coverage* ------		
		ANOVA, RCB design, 13 treatments		
Source[z]	Rate[y]			
Ammonium nitrate	8	0.8	13.8	30.5
Milorganite	8	16.5	39.3	47.0
Nutralene	8	1.5	10.8	45.8
Polyon	8	2.3	15.0	37.0
Ammonium nitrate	6	0.5	5.5	30.3
Milorganite	6	4.5	14.5	49.3
Nutralene	6	0.3	2.8	33.5
Polyon	6	0.3	8.0	40.8
Ammonium nitrate	4	0.0	1.0	22.0
Milorganite	4	0.8	7.0	29.8
Nutralene	4	0.5	15.8	55.0
Polyon	4	0.3	5.8	55.3
Check	0	0.0	7.0	50.0
LSD, $P=0.05$[x]		5.9	16.3	NS
Randomized complete block design effects *(P)*				
Treatment		0.0002	0.0067	0.8680
		ANOVA, 4 × 3 factorial design, 12 treatments		
Source[z]				
Ammonium nitrate		0.4	6.8	27.6
Milorganite		7.3	20.3	42.0
Nutralene		0.8	9.8	44.8
Polyon		0.9	9.6	44.3
LSD, $P=0.05$[x]		3.6	9.6	NS
Rate[y]				
8		5.3	19.7	40.0
6		1.4	7.7	38.4
4		0.4	7.4	40.5
LSD, $P=0.05$[x]		3.1	8.3	NS
Factorial design effects *(P)*				
Source (S)		0.0009	0.0377	0.3964
Rate (R)		0.0070	0.0066	0.9761
S x R		0.0153	0.1025	0.7408

[z] Sources include: Ammonium nitrate 34-0-0, Milorganite 6-2-0, Nutralene 40-0-0, and Polyon 43-0-0 (March and October) and Polyon 42-0-0 (May and August).

[y] Annual rates as lb N/1000 ft^2 per year. Applied 15 Nov. 2003 and 15 Mar., 18 May, 16 Aug., and 2 Nov. 2004.

[x] Mean separation within columns and treatment factors by Fisher's protected LSD test, $P=0.05$.

Table 35. Analysis of chemical and physical properties of the soil at the UC Davis site performed before sod was laid in Oct. 2002.

	Oct. 2002
Soil salinity/alkalinity/toxicity[z]	
pH	6.8
Soluble Ca (ppm)	86
Soluble K (ppm)	33
Soluble Mg (ppm)	78
Soluble Na (ppm)	115
SAR	2
ESP (%)	2
CO_3 (ppm)	<3
HCO_3 (ppm)	122
CEC (meq/100 g)	19.0
Soil fertility[z]	
Extractable Fe (ppm)	19.5
Olsen-P (ppm)	37.8
Exchangeable K (ppm)	395
Exchangeable Ca (ppm)	1663
Exchangeable Mg (ppm)	1058
Exchangeable Na (ppm)	174
TKN (%)	0.024
Soil characteristics[z]	
OM (%)	1.69
Sand (%)	40
Silt (%)	45
Clay (%)	15

[z]Analyses conducted according to relevant DANR analytical methodologies.

APPENDIX

CONFERENCE SPONSORSHIP

This field day is sponsored by UC Cooperative Extension, the UC Riverside Department of Botany and Plant Sciences, and Agricultural Operations. Cooperation is also provided by members of the Green Industry.

PROGRAM COORDINATORS

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UNIVERSITY OF CALIFORNIA
RIVERSIDE

PRESENTS

TURFGRASS

AND

LANDSCAPE MANAGEMENT

FIELD DAY

TUESDAY, SEPTEMBER 24, 2002

7:30 A.M. – 12 NOON

AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF CALIFORNIA
RIVERSIDE, CALIFORNIA

GENERAL INFORMATION

This field day is ***designed to relate research results and observations of ongoing, or recently completed, research projects*** at the University of California, Riverside (UCR) and the greater southern California region. The topics will be of interest to individuals who need to keep abreast of current activities regarding turfgrass and landscape management, cultural practices, and pest management.

CREDIT HOURS

Requests have been made for Pest Control Continuing Education Credits, ISA, and CCN Pro Continuing Education Credits.

COST

The cost is $30.00 per person payable with the registration form. Continental breakfast, refreshments, and proceedings will be provided.

REGISTRATION

Registration must be **received** by **mail on or before** **September 18, 2002**.

You will receive written confirmation of your registration and fee payment if received by the deadline. A registration packet and admission badge will be issued to each registrant at the registration desk. **The badge must be worn for admittance.**

The field day program will be held at the UC Riverside Agricultural Operations facility. Please use the Canyon Crest Drive entry gate.

Please note:

Registration is on a first-come, first-served basis.

Telephone registrations cannot be taken. Registration is final and there can be **no refunds**.

TURFGRASS AND LANDSCAPE MANAGEMENT FIELD DAY
TUESDAY, SEPTEMBER 24, 2002

7:30 a.m. Registration and Refreshments

8:30 **Welcome and Organizational Details**
Victor Gibeault and Cheryl Wilen

Stop 1 **Green Waste Compost as a Turf Soil Amendment**
Steve Ries, Staff Research Associate, Agricultural Operations, UC Riverside

Stop 2 **Landscape-Applied Pesticide Impact on Urban Water Quality**
Jay Gan, Extension Water Quality Specialist, Dept. of Environmental Sciences, UC Riverside

Stop 3 **Transplanting Palms: Effects of Leaf Removal and Tie-up**
Dennis Pittenger, Area Environmental Horticulturist, UCCE, Central Coast and South Region/UC Riverside
Donald Hodel, Environmental Horticulture Advisor, UCCE, Los Angeles County

Stop 4 **New Fungicides for Turf Disease Control in California**
Frank Wong, Plant Pathology Specialist, Dept. of Plant Pathology, UC Riverside

10:00 a.m. BREAK, Refreshments

Stop 5 **Development of Nitrogen BMPs for Fertilizing Lawns**
Laosheng Wu, Water Management Specialist, Dept. of Environmental Sciences, UC Riverside

Stop 6 **Influence of Planting Procedures on Woody Plant Establishment**
Donald Merhaut, Extension Nursery and Floriculture Crops Specialist, Dept. of Botany and Plant Sciences, UC Riverside

Stop 7 **Dry-Down Response of Bermudagrass Cultivars and New NTEP Studies**
Victor A. Gibeault, Extension Environmental Horticulturist, Dept. of Botany and Plant Sciences, UC Riverside

Stop 8 **Landscape Weed Identification and Management**
David Cudney, Extension Weed Science Specialist, Dept. of Botany and Plant Sciences, UC Riverside

11:50 a.m. Conclude Program

Detach and mail with your check.

REGISTRATION FORM:

____ Turfgrass & Landscape Field Day, Sept. 24, 2002 $30.00

PLEASE PRINT OR TYPE INFORMATION.
NO PURCHASE ORDERS OR CREDIT CARDS ACCEPTED.
REGISTRATION IS FINAL AND THERE CAN BE NO REFUNDS.

Make check or money order payable to:

Regents, University of California
(Your registration will be confirmed.)

Employer ________________________

Name ________________________
(first) (last) (phone)

Address ________________________
(street) (city, state) (zip)

Mail check and registration form to:
Registration Coordinator/Turf & Landscape Conf.
4106 Batchelor Hall Extension
Department of Botany and Plant Sciences
University of California
Riverside, CA 92521-0124
Tel. No. (909) 787-4430 / FAX (909) 787-5717
e-mail: susana@citrus.ucr.edu

Registration closes on September 18, 2002

Eleventh Annual

Fertilizer Research and Education Program Conference
November 20, 2003
EDISON AgTAC
Tulare, California

Sponsored By
California Department of Food and Agriculture
California Plant Health Association
California Certified Crop Adviser Program

CCA/PCA credits will be available.

Background
Since 1991, the California Department of Food and Agriculture's (CDFA) Fertilizer Research and Education Program (FREP) has funded more than 100 projects that promote the environmentally safe and agronomic sound use of fertilizing materials in California, FREP is a recognized leader in advancing the knowledge and understanding of complex nutrient management issues for many California cropping systems. The program strives to provide growers and the industry with cost-effective ways to improve fertilizer use efficiency and minimize environmental impacts. CDFA and its co-sponsors invite you to learn about the latest efforts to improve nutrient management, protect water sources, and improve growers' economic viability.

This year's conference will focus on updates of current and recently completed research projects for many California cropping systems. The program will feature:

Governmental Update

- Site specific nutrient management and variable rate fertilizer application
- Nitrate availability and leaching under different fertigation strategies
- Development of Best Management Practices for lawns
- New job for CCA's?
- Fertilization of California wheat
- Improving capabilities of detecting Molybdenum deficiency in alfalfa
- Evaluation of fertilization practices in the Salinas Valley
- Mass balance of cropland soils
- Ammonia emissions related to fertilizer application practices
- Nutrient uptake and crop load for the 'Hass' avocado

Who Should Attend
CDFA/FREP invites agricultural supply and service organization representatives, PCA's and CCA's, growers, university specialists, and public officials, as well as other interested parties to attend this year's conference. PCA/CCA credit will be offered.

CONFERENCE PROGRAM

8:00 Registration

8:30 - 8:40 ***Welcoming Remarks***
Stephen Mauch, Director, Division of Inspection Services, California Department of Food and Agriculture

8:45 - 9:15 ***Governmental Update***
Steve Beckley, President, California Plant Health Association

9:15 - 9:45 ***Evaluation of Slow Release Fertilizers for Cool Season Vegetable Production in the Salinas Valley***
Richard Smith, UC Cooperative Extension

9:45 - 10:15 ***Effficient Phosphorus Management in Coastal Vegetable Production***
Tim Hartz, UC Davis, Department of Vegetable Crops

10:15 - 10:30 BREAK

10:30 - 11:00 ***Development of BMP for Fertilizing Lawns to Optimize Plant Performance and Nitrogen Uptake While Reducing the Potential for Nitrate Leaching***
Robert Green, UC Riverside, Department of Botany and Plant Science

11:00 – 11:30 ***Nitrogen Fertilization and Grain Protein Content In California Wheat***
Lee Jackson, UC Davis, Department of Agronomy and Range Science

11:30- 12:00 ***Trace Element Mass Balance of Cropland Soils***
Andrew C. Chang, UC Riverside, Department of Environmental Sciences

12:00 - 1:00 LUNCH
Presentation:
Comprehensive Nutrient Management Plans: A New Job for CCA's
Robert Fry, USDA, Natural Resource Conservation Service

1:00 - 1:30 ***Improving the Diagnostic Capabilities for Detecting Molybdenum Deficiency in Alfalfa and Avoiding Toxic Concentrations for Animals***
Roland D. Meyer, UC Davis, Department of Land, Air and Water Resources

1:30 -2:00 ***Development of Lime Recommendations for California Soils***
Robert Miller, Colorado State University, Soils and Crop Science Department

2:00 - 2:30 ***Crop Nitrate Availability and Nitrate Leaching under Micro-Irrigation for Different Fertigation Strategies***
Blaine Hanson, UC Davis, Department of Land, Air and Water Resources

2:30 – 2:45 BREAK

2:45 – 3:45 **Breakout Sessions I and II**

SESSION I: Nitrogen Application Strategies

Site-Specific Variable Rate Fertilizer Nitrogen Application in Cotton
Richard E. Plant, UC Davis, Department of Agronomy and Range Science

Ammonia Emission Related to Nitrogen Fertilizer Application Practices
Charles F. Krauter, CSU Fresno, Center for Irrigation Technology

SESSION II: Effects of Nutrient Management on Tree Crop Production

Seasonal Patterns of Nutrient Uptake and Partitioning as a Function of Crop Load of the 'Hass' Avocado

Richard Rosecrance, CSU Chico, School of Agriculture

The Effect of Nutrient Deficiencies on Stone Fruit Production and Quality

Scott Johnson, UC Davis, Department of Pomology


Register Today
SCTC's 45th Annual
Turfgrass and Landscape
New Location
Institute
Southern California Turfgrass Council
December 10, 2003 • 6:30 a.m. - 3:30 p.m.
Ontario Convention Center • Ontario, California
Co-Sponsored by:
SOUTHERN CALIFORNIA TURFGRASS COUNCIL
and UNIVERSITY OF CALIFORNIA COOPERATIVE EXTENSION
THE UNIVERSITY OF CALIFORNIA 1868
Featuring 6 Full-day Educational Sessions:
• Landscape Management (En Español)
• Turfgrass and Landscape Management • Irrigation Management
• Sports Turfgrass and Park Management
• Arboriculture • Golf Course Management
New General Session:
California's Emerging Environmental Challenges: A Framework for Tomorrow
6 - 6.5 PCA, QAL, QAC hours; 5.5 ISA hours; .6 GCSAA PDUs
with 2.0 optional LAWS & REGULATIONS hours.
Complete your 2003 educational requirements at the Institute!

Breakout Session 3

Turfgrass and Landscape Management

Continuing Education Units Applied for:
4.5 PCA,QAL,QAC hours; 3.0 ISA hours;
.45 GCSAA PDUs

Moderator: Bill Baker

9:00 - 9:45 **Innovations in Drip Irrigation**
Travis Komara

9:45 - 10:15 **Irrigating with Reclaimed Water: Opportunities for the Landscape Industry**
Valerie Mellano

10:15 - 10:45 **Break and Trade Show**

10:45 - 11:15 **Introducing the New UC Riverside Turfgrass Website: A Wealth of Practical Knowledge**
Grant Klein

11:15 - 12:00 **Common Winter Turfgrass Diseases: Identification and Integrated Pest Management Strategies**
Larry Liggett

12:00 - 1:30 **Lunch and Trade Show**

Moderator: Paul Santos

1:30 - 2:15 **Nitrogen Management in Landscapes to Minimize Leaching**
Janet Hartin

2:15 - 3:00 **Mosquito Control and West Nile Virus Update**
Minoo Madon

Breakout Session 7

Golf Course Management

Continuing Education Units Applied for:
4.5 PCA,QAL,QAC hours; .45 GCSAA PDUs

Moderator: Pat Gross

9:00 - 9:30 **Nitrogen Leaching on Golf Courses**
Janet Hartin

9:30 - 10:00 **New *Poa annua* Var. Reptans Selections for Use on Putting Greens**
David Green

10:00 - 10:30 **Break and Trade Show**

10:30 - 11:00 **Fate of Pesticides Applied on Turfgrass**
Jay Gan

11:00 - 11:30 **The Potential Impact of Water Quality Regulations on Golf Courses**
Laosheng Wu

11:30 - 12:00 **Golf Course Water Use Efficiency – Why It's Important**
Robert Green

12:00 - 1:00 **Lunch and Trade Show**

1:00 - 1:30 **Update on the Development of Roundup-Ready Bentgrasses**
Kevin Turner

1:30 - 2:00 **Golf Course Maintenance and the Art of Good Communication**
David Wienecke

2:00 - 2:30 **Navigating the UCR Turfgrass Website**
Grant Klein

2:30 - 3:00 **The Year in Review: Observations From the USGA Green Section**
Pat Gross

UNIVERSITY OF CALIFORNIA TURFGRASS RESEARCH ADVISORY COMMITTEE

TURFGRASS TOUR

Tuesday, June 8, 2004

Welcome to UCR Agricultural Operations
Steve Cockerham, Superintendent, Agricultural Operations

Stop 1. A New Minimum Maintenance Study: Alternative Grass Performance
Vic Gibeault, Extension Environmental Horticulturist, Ret.

Stop 2. Using Lysimeters As A Method For Determining Turf Water Use
Steve Ries, Staff Research Associate, Agricultural Operations and Steve Cockerham

Stop 3. Nitrogen Fertilization And Leaching Study On Tall Fescue
Robert Green, Turfgrass Research Specialist,

Stop 4. New Fungicides For Dollar Spot Control
Frank Wong, Plant Pathology Specialist

Stop 5. Environmental Issues Of Using Treated Wastewater For Irrigation
Jay Gan, Soil Science Cooperative Extension Specialist

AGENDA

UCRTRAC

June 8, 2004

Agricultural Operations Conference Room
1060 Martin Luther King Blvd.
University of California, Riverside

9:00 a.m. Welcome

Coffee and donuts

Self introductions

9:15 a.m. Greening the California's Economy

Kathleen Peach

Sue McKee

UCRTRAC Delegate Impressions

9:40 a.m. A Brainstorming Session on the UCR Turfgrass Project

Dr. Donald Cooksey and Delegates

11:00 a.m. Field Tour of Turfgrass Research Activities

Noon Lunch at the Turf Facility

1:00 p.m. Adjourn

Next Meeting December 7, 2004

CHICO PAPA SEMINAR

Masonic Family Center

1110 W. East Avenue, Chico, CA 95926

November 4, 2004

(7 DPR have been requested, including laws. Please go to DPR's website, **www.cdpr.ca.gov** for final accreditation)

7:00	**Registration**
7:30	**Continuing Education & License Renewal Regulations** *Charlotte Carson – PAPA*
7:45	**Transporting Hazardous Materials** *Dan Cantieri - California Highway Patrol*
8:45	**Update on West Nile Virus** *Charlotte McCord – Butte County MVCD*
9:15	**Break**
9:30	**Fish and Game Trapping Licensing Regulations Update** *Joe Gonzales – CA Dept Fish & Game*
10:30	**Reducing Greenwaste in Urban Landscapes** *Ken Decio – CA Integrated Waste Management*
11:15	**Phytophthora/oak Root Fungus** *Denice Britton – Britton Tree Service*
12:00	**Lunch**
12:45	**Best Management Practices for Tall Fescue** *David Burger – UC Davis*
1:45	**ID & Control of Destructive Mites in Ornamental Trees** *ana Bartel* **–** *Crompton Corp./Uniroyal*
2:30	**Fertilization to Enhance Pest Management** *Dave Barlow – JR Simplot*
3:15	**Meeting Ends - *Thanks for Attending!***

DIRECTIONS

From Fwy 99: Exit west on the East Avenue exit. Continue west across the Esplanade to 1110 W. East Avenue (approximately 2 miles) From I-5: Take Hwy 32 exit towards Hamilton City & Chico. Coming into Chico turn left on W. East Avenue (signal light). The Center is approximately 3 blocks on the left.

MONTEBELLO PAPA SEMINAR

Quiet Cannon Conference Center
901 N. Via San Clemente, Montebello, CA 90640
June 7, 2005

(8 DPR hours have been approved, including 3.5 laws)

7:00 Registration

7:15 Continuing Education and Renewal Information

Betty Dolcater – PAPA

CONCURRENT SESSIONS

	Room A	Room B
7:30	**Workers Compensation/Worker Safety Regulations** Jeannette Heinrichs – Van Beurden Insurance Services	**Regulations On Transporting Hazardous Materials On Southern CA Highways** **[Detailed 4 hour presentation Per Request of the CHP]** Dan Cantieri – CA Highway Patrol
8:30	**Worker Safety Protection Program** **For Pesticide Applicators & Pesticide Toxicity** Syed Murtaza – Dewey Pest Control	**Regulations On Transporting Hazardous Materials On Southern CA Highways** **[talk continues]** Dan Cantieri – CA Highway Patrol
9:30	**Break**	
9:45	**Identification and Safe Handling Of Snakes** Michael Glassey – All Pro Environmental Services	**Regulations On Transporting Hazardous Materials On Southern CA Highways** **[talk continues]** Dan Cantieri – CA Highway Patrol
10:45	**PRESCRIBE – Online Database Applications For Endangered Species & Pesticide Regulations** Polo Moreno – CDPR	**Regulations On Transporting Hazardous Materials On Southern CA Highways** **[talk continues]** Dan Cantieri – CA Highway Patrol

11:30 Lunch

	Room A	Outside
12:30	**Diagnostics: ID Of Biotic and Abiotic Plant Diseases** Janet Hartin – UCCE LA County	**Weed ID and Control Demonstration** Bruce Kidd – Dow Agro Sciences
1:15	**The Use Of Botanical Pesticides In An IPM Program** Ramon Georgis – EcoSMART Technologies	**Using An Arborists Report For Pest and Disease Identification As Part Of An IPM Program** Mike Ventura – Ventura's Pest Control
2:30	**Difficult Weeds Or Herbicide Resistance?** Bruce Kidd – Dow	**Organic Hot Foam Weed Control** Ian Webster – Waipuna
3:15	**Rodent Control Techniques** James Osuch – Bell Labs	**Organic Hot Foam Weed Control Continues**

4:15 End of Program – Thanks for Coming!

DIRECTIONS

From Orange & San Bernardino Counties: Go West on the 60 Fwy to Wilcox Ave/Garfield Ave exit. Continue on the exit to the 2nd signal which is Garfield Ave., turn left [south]. Go to Via San Clemente, turn right and go to the top of the hill to the clubhouse.

From Los Angeles & San Fernando Valley: Go east on the 60 Fwy [Pomona Fwy] to the Garfield Ave/Wilcox Ave exit. Turn right at the signal [south] which is Garfield Ave. Go to the first street, Via San Clemente, turn right and go to the top of the hill to the clubhouse.

November 30, 2005
National Steinbeck Center
Salinas, California

Sponsored By

California Department of Food and Agricu
Western Plant Health Association
California Certified Crop Advisor Program

CONFERENCE PROGRAM

8:00 – 8:30 Registration

8:30 - 8:40 Welcoming Remarks
Nate Dechoretz, Director, Division of Inspection Services, California Department of Food and Agriculture

8:40 - 9:00 Governmental Update
Renee Pinel, President, Western Plant Health Association

9:00 - 9:40 Vegetable Fertilization in California
Timothy Hartz, UC Davis, Department of Vegetable Crops

9:40 - 10:00 New Fertilizing Materials
Robert Mikkelsen, Potash and Phosphate Institute

10:00 - 10:15 BREAK

10:15 - 10:45 Development of BMPs for Fertilizing Lawns to Optimize Plant Performance and Nitrogen Uptake While Reducing the Potential for Nitrate Leaching
Robert Green, UC Riverside, Department of Botany and Plant Sciences

10:45 - 11:15 Determination of Nursery Crop Yields, Nutrient Content and Water Use for Improvement of Water and Fertilizer Use Efficiency
Richard Evans, UC Davis, Environmental Horticulture

11:15 - 11:45 Precision Fertigation in Orchards: Development of a Spatially Variable Microsprinkler System
Michael Delwiche, UC Davis, Department of Biological and Agricultural Engineering

11:45 - 12:45 LUNCH

12:45 – 3:00 Afternoon Sessions

Crop and Nutrient Management Session

12:45 – 1:15 Seasonal Patterns of Nutrient Uptake and Partitioning as a Function of Crop Load of the 'Hass' Avocado and Rate of Fertilization
Carol Lovatt, UC Riverside, Department of Botany and Plant Sciences

1:15 – 1:45 Improving the Procedure for Nutrient Sampling in Stone Fruit Trees
R. Scott Johnson, UC Davis, Department of Pomology

1:45 – 2:00 BREAK

2:00 – 2:30 Planning Application Rates for Organic Fertilizers
David Crohn, UC Riverside, Department of Soil and Environmental Sciences

2:30 – 3:00 Ammonia Emission Related to Nitrogen Fertilizer Application Practices
Charles Krauter, CSU Fresno, Center for Irrigation Technology

Pesticide and Water Quality Management Session

12:45 – 1:15 Effective Choices for Disease Control
Ann Chase, Chase Research Gardens

1:15 – 1:45 Update on the Agricultural Irrigation Return Flow Waiver
Central Coast Regional Water Quality Board

1:45 – 2:00 BREAK

2:00 – 2:30 Using Polyacrylamide (PAM) for Controlling Sediments and Nutrients in Irrigation Runoff from Central Coast Vegetable Fields
Michael Cahn, UC Cooperative Extension

2:30 – 3:00 Effects of Conservation Tillage on Nutrient Losses to Runoff in Alternative and Conventional Farming Systems
William Horwath, UC Davis, Department of Land, Air and Water Resources

who For All Landscape and Turf Related Professionals

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Over 300 Exhibits, 20 Early Ford classic cars on display courtesy of Mission Trail, Demo Zones

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Turf and Landscape EXPO 2006 Events

42nd Annual Northern California Turf and Landscape Exposition Educational Program

TURF AND LANDSCAPE EXPO EDUCATIONAL PROGRAM
WEDNESDAY, FEBRUARY 1, 2006

ROOM	TIME	TITLE/SPEAKER
J&K	7:30-9:30 AM	**MANAGING LOW BUDGET SPORTS AND PARK TURF (INCLUDING IPM)** Dr. Ali Harivandi, UC Cooperative Extension
J&K	9:45-11:15	**Sponsored by GCSANC** **Golf Course Maintenance and Regulatory Compliance** Dave Davies, CGCS Callippe Preserve Golf Course
J&K	10:30-11:15	**Golf Course Maintenance: Past, Present, and Future. Where Will We Be 50 Years From Now?** Terry Grasso, CGCS, Sequoyah Country Club
J&K	11:15-12:30PM	****VISIT TRADE SHOW****
J&K	12:30-2:30	**Best Management Practices for Tall Fescue Nitrogen Fertilization to Reduce Ground Water Pollution** Dr. Dave Burger, UC Davis **An Update on Northern California Turfgrass Diseases and Their Management** Dr. Frank Wong, UC Riverside
J&K	2:30-4:00	**Chemigation - Ground Water Protection** Bill Green, CIT CSU Fresno
GA1&2	7:30-8:30 AM	**Pesticide Safety Review** Mario Nunes, Agricultural Biologist, County of Santa Clara **Santa Clara County IPM Update** Nareesh Duggal, IPM Coordinator Santa Clara County
GA1&2	9:00-12:00	**IRRIGATION** MANAGEMENT **IPM thru Irrigation Techniques**
GA1&2	12:00PM-1:00	****VISIT TRADE SHOW****
GA1&2	1:00-3:00	**Prescribe - Endangered Species Database** Polo Moreno, DPR
GA3	7:30-8:30 AM	**Sponsored by Irrigation Association** (IA) **SMART Technologies for Irrigation Management** 8 Hours IA CEU's. **Note: Pay Fee to IA directly. ($150 IA Mem; $175 NCTLC Mem; $200 Non-Mem) Pricing for registration prior to 1/18/06.**
GA3	12:00-1:OOPM	****VISIT TRADE SHOW****
GA3	1:00-5:00	**IA Class Continued**

Visit Us & Register Online
www.nctlc.com

TURF AND LANDSCAPE EXPO EDUCATIONAL PROGRAM
THURSDAY, FEBRUARY 2, 2006

ROOM	TIME	TITLE/SPEAKER
J&K	7:00-9:00 AM	**Adult Plant Doctor Training** Rick Foell, Stanley Strew Foundation **Where Are We Now?** Mr. Terry Stark, Executive Director CAPCA
J&K	9:00-11:00	**Recognizing and Correcting Problems and Pests in the Root Zone of Landscape Plants** Dr. Larry Costello, UC Cooperative Extension
J&K	11:00-1:00 PM	****VISIT TRADE SHOW****
J&K	1:00-3:00	**TREE** MANAGEMENT **IPM Techniques Utilizing Visual Assessment and Soil Demonstrations** Ray Morneau, Morneau Consulting **Root Crown Excavation of Trees** Torrey Young, Treescapes, Inc.
		SPANISH ONLY SESSION
GA1	9:00-11:00 AM	**Manejamiento de Un Control Integrado en el Jardin (Integrated Pest Management in the Landscape)** Dr. Maria del la Fuente
GA1	11:00-12:OOPM	**Irrigation Management** Rainbird Corporation
	12:00-1:OOPM	****VISIT TRADE SHOW**** **Visitia A los Establecimientos de la Exposicion**
GA1	1:00-2:30	**Chemigation - Ground Water Protection** Bill Green, CIT CSU Fresno
GA2	10:00-12:00PM	**Sponsored by Integrated Waste Mgmt Group** **Sustainable Landscaping; Benefits of Becoming a Green Landscaper**
GA2	1:00-2:30	**VEGETATION MANAGEMENT SESSION** **Environmental Stewardship; Noxious Weeds; Detection, Identification & Control** Ed Finley, CDFA **Right of Way Management Thru IPM** Don Bartel, Sierra Consulting
GA3	8:00-9:00 AM	**Sponsored by Irrigation Association (IA)** **Advanced Irrigation Design for Water Conservation** 8 Hours IA CEU's. **Note: Pay Fee to IA directly. ($175 IA Mem; $190 NCTLC Mem; $210 Non-Mem) Pricing for registration prior to 1/18/06.**
GA3	12:00-1:OOPM	****VISIT TRADE SHOW****
GA3	1:00-5:00	**IA Class Continued**

Back to Seminar Listings

PAPA SEMINAR
SAN BERNARDINO/ CUCAMONGA

Etiwanda Gardens
7576 Etiwanda Ave, Rancho Cucamonga, CA 91739
May 10, 2006
(7 DPR hours have been requested, including laws. Please go to DPR's website, www.cdpr.ca.gov for final accreditation information)

7:00	**Registration**
7:15	**Continuing Education & License Renewal Review** *Betty Dolcater – PAPA*
7:30	**Worker Safety : Venomous Snake Identification** *Michael Glassey – All Pro Environmental Services*
8:30	**Nutsedge Control** *Steven Gould - Monsanto*
9:00	**BREAK**
9:15	**Regulatory Issues Regarding Diaprepes Root Weevil Infestation** *Laura Petro - CDFA*
10:00	**Risk Management: Liability Insurance Claims Procedures** *Jeannette Heinrichs – Van Beurden Insurance Services*
11:00	**Integrated Pest Management and Bed Bugs** *Sam Makhani – Western Exterminator Company*
11:45	**LUNCH**
12:30	**Personal Protective Equipment Update** *David Weinecke – Braemar Country Club*

CONCURRENT SESSIONS

	Inside – Room A	Outside – A	Outside - B
1:00	**Importance of Using Adjuvants In Your Spray Program** *Rick Foell – Simplot Grower Solutions*	**Understanding Soil Types and How They Absorb Water As Part Of An IPM Program** *Janet Hartin - UCCE*	**Please Don't Kill This! California Native Plants In The Landscape** *Barbara Eisenstein – Rancho Santa Ana Botanic Garden & Ellen Mackey – LA County Watershed*
2:00	**Breakthrough In Natural and Organic Practices: Understanding The Importance Of Mycorrhizal Fungi and Building The Microbial Life Of Your Soil -** *Gisele Schoniger – Kellogg Garden Products*	**Contolling Rodents, Rabbits and Bees** *Bruce Cahill – Wildlife Pest Management*	**No Session**

3:00 **Program Ends - Thanks for Coming!**

DIRECTIONS

From Eastbound 210: Exit at Dry Creek Blvd, take Dry Creek Blvd South 1 mile to Baseline Rd. Turn left onto Baseline Rd. east to Etiwanda Ave. Turn Right on Etiwanda Ave about 1/3 mile to 7576 Etiwanda Ave on your right.

From Northbound I-15: Exit at Foothill Blvd/Historic Rt 66, travel east about ½ mile to Etiwanda Ave. Turn left[north] onto Etiwanda Ave about 7/10 mile to 7576 Etiwanda Ave on your left. Watch for sign for Etiwanda Gardens

From Southbound I-15: Bear right onto off-ramp for Baseline Rd. Turn Right onto Baseline Rd, travel about ½ mile to Etiwanda Ave, turn left onto Etiwanda Ave, travel about 1/3 mile to 7576 Etiwanda Ave .- Watch for sign for Etiwanda Gardens.

From East or Westbound I-10, Take 1-15 North and follow directions above.

THE CUYAMACA COLLEGE
BOTANICAL SOCIETY, THE
UNIVERSITY OF CALIFORNIA
COOPERATIVE EXTENSION,
AND THE CITY OF SAN DIEGO PARKS AND
RECREATION DEPARTMENT

Present

THE 17TH ANNUAL

TURF MANAGEMENT SEMINAR

"Implementing Turf Research Results"

FRIDAY - MARCH 10, 2006
6:30 AM to 3:00 PM

17th ANNUAL
TURF MANAGEMENT SEMINAR
PROCEEDINGS

- **REGISTRATION AND EXHIBITS**
- **WELCOME AND ANNOUNCEMENTS**

MORNING SESSIONS

- ***WATERSHED PROTECTION AND PEST MANAGEMENT ISSUES FOR TURFGRASS MANAGERS***
  Mr. Paul Davy, County of San Diego

- ***EFFECTIVE WETTING AGENTS AND TOOLS FOR WATER CONSERVATION/RUNOFF REDUCTION***
  Dr. Shoumo Mitra, Cal Poly Pomona

- ***DEVELOPMENT OF FERTILIZATION BMP'S TO OPTIMIZE PLANT PERFORMANCE AND NITROGEN UPTAKE WHILE REDUCING THE POTENTIAL FOR NITRATE LEACHING***
  Dr. Robert Green, UCR

- **BREAK WITH VENDOR EXHIBITS**

- ***PRACTICAL TURFGRASS MANAGEMENT: SITUATIONS - CULTURAL PRACTICES - PEST MANAGEMENT***

  MULCHES: EFFECTIVE WEED CONTROL BUT THEY CAN EVAPORATE AS MUCH WATER AS TURF!
  Mr. David Shaw, UC Cooperative Extension, San Diego

DEVELOPMENT OF NITROGEN BMPS FOR FERTILIZING LAWNS

Grant J. Klein[1], Robert L. Green[1], Laosheng Wu[2], David W. Burger[3], Janet S. Hartin[4], and Melody Meyer[3]

[1]Dept. of Botany and Plant Sciences, University of California, Riverside, CA 92521
[2]Dept. of Environmental Science, University of California, Riverside, CA 92521
[3]Dept. of Environmental Horticulture, University of California, Davis, CA 95616
[4]University of California Cooperative Extension, San Bernardino and Los Angeles Counties
777 E. Rialto Avenue, San Bernardino, CA 92514

The definition of the phrase "best management practice" (BMP) varies depending on the specific context involved and the currently accepted standards and goals of agronomic management. In general, BMPs are considered to be a set of guidelines or procedures which have been determined, as part of an overall program, to be an effective and practical (technically, socially and economically) method for reducing, preventing, or controlling undesirable effects of management; promoting or maintaining beneficial effects of management; and/or protecting the environment or natural habitat. Turfgrass-related BMPs encompass a wide variety of activities, including fertilization, irrigation, mowing, pest control, and soil management. One of the most important set of turfgrass BMPs are those relating to providing adequate nitrogen (N) to provide the healthy, moderate (i.e., neither minimal or excessive) growth necessary to provide both acceptable visual appearance and the ability to cope with stresses such as drought, traffic, and disease.

Promoting moderate growth (and optimal uptake of N by the plant) is, in fact, one of the best defenses against N sources contaminating the environment. Nitrogen that isn't taken up by the plant is either stored in the soil or thatch, lost to the atmosphere [NH_3 volatilization and denitrification (the reduction of nitrates to gaseous nitrogen)], or lost to surface water in runoff or groundwater via leaching.

In the soil environment, the primary forms of N are organic N (the dominant form), ammonium-N (NH_4^+-N), nitrite-N (NO_2^--N), and nitrate-N (NO_3^--N). Unlike organic N and NH_4^+-N, nitrates do not bind to soils and thus have a high potential for leaching into groundwater. However, it should be noted that organic N and NH_4^+-N are potential nitrate sources, since they can be transformed to nitrate in soil and waters. Nitrate is also likely to remain in the water supply until consumed by plants or other organisms since they do not volatize. According to the U.S. Environmental Protection Agency (EPA), nationwide over 112 million pounds of nitrate and nitrite were released to water and land from 1991 through 1993. Notably, one of the largest releases of inorganic nitrates (from sources such as fertilizers) was in California.

Excessive N in the environment can have serious consequences, including altering ecosystems, eutrophication [an over-enrichment of water sources with nitrogen and phosphorus which causes accelerated growth of plant life (such as algal blooms) and which can disturb the balance of organisms and water quality], contributing to acid depostion and ozone depletion, and, as already noted, contamination of surface water and groundwater. According to the U.S. Department of Health and Human Services, N fertilizers have contributed to a 40-year trend of increased nitrate levels in surface water and groundwater of agricultural regions.

This increased level of nitrates in groundwater has some serious health implications if it enters into the water supply. The current safety guidelines for nitrate contamination of water were established in 1974 with the Safe Drinking Water Act. The maximum contaminant level (MCL) for nitrates was set to 10 ppm (1 ppm for nitrites), which is considered to be low enough to avoid any potential health problems. Although acute nitrate poisoning of humans is rare, at levels beyond 10 ppm, nitrate in drinking water can cause serious illness and even death. Infants are particularly susceptible to a disease of the blood supply in which the oxygen-carrying capacity of the blood is affected by conversion of nitrate to nitrite by the body. Long-term health issues (which result from a lifetime of exposure at levels beyond the current government standards) include diuresis (increased excretion of urine) and increased starchy deposits and hemorrhaging of the spleen.

Given the potential implications of nitrate contamination, turfgrass fertilization BMPs must take into account ways to minimize nitrate contamination of surface water and groundwater. Research has shown that nitrate contamination of surface water due to runoff is rare due to the relatively high infiltration capacity of turfgrass ecosystems (with the exception of severe slopes, which require careful irrigation cycling). The results of research on nitrate leaching, however, are more variable, with soil type, irrigation, N source and rate, and season of application all potentially affecting nitrate leaching.

The objectives of the research project are to 1) evaluate the annual N rate and source on tall fescue to determine which treatments optimize plant performance and N uptake while reducing the potential for nitrate (NO_3^-) leaching; 2) quantify the effect of N fertilizer rate and source on visual turfgrass quality and color, clipping yield, tissue N concentration, N uptake, and concentration of NO_3^--N at a depth below the rootzone; 3) develop BMPs for lawns under representative irrigation practices to optimize plant performance and N uptake while reducing the potential for NO_3^- leaching; and 4) conduct outreach activities, including oral presentations and trade journal publications, emphasizing the importance of the BMPs and how to carry out these practices for N fertilization of lawns.

The project is being conducted at two sites with different climates and turfgrass maturity, but which are being maintained similarly. One site is a newly established tall fescue plot (sodded late Sept. 2002) in northern California at UC Davis and the other is a mature tall fescue plot (seeded Apr. 1996) in southern California at UC Riverside. Both sites were established to tall fescue, since it is the most widely used lawngrass in California, especially for urban landscapes. The plots at both sites are irrigated at [100% ET_{crop}/DU] minus rainfall, with the amount of irrigation determined weekly based on the previous 7 days' cumulative ET_o. There are two irrigation events per week, which are cycled to prevent runoff. The experimental design at both sites is a randomized complete block (RCB) design with N treatments arranged in a 4×3 factorial (four N sources and three rates). A no-nitrogen check treatment is also included to allow for additional statistical tests. The application of treatments and data collection will be coordinated between the two sites in order to allow for the most robust statistical analyses possible for comparing the results from the two sites.

Both quick release and slow release N sources are included in the study, both of which have distinct advantages and disadvantages relative to the other. Quick release N sources provide a rapid but short-term turfgrass response while slow release N sources provide a slow but long-term response. Quick release sources are generally less expensive and more efficient (in terms of the percentage of applied N recovered in grass clippings) than slow release N sources, but also have the greater tendency for foliar burn, volatilization and leaching. The specific N sources used in the study include: ammonium nitrate, a fast-release, water soluble N source; Polyon, a slow-release, polymer-coated N source; Milorganite, a slow-release, natural organic N source; and Nutralene, a slow-release, water insoluble, methylene ureas N source.

Each fertilizer will be applied at three annual N rates, including a low (4.0 lb N/1000 ft^2), moderate (6.0 lb N/1000 ft^2) and high (8.0 lb N/1000 ft^2) rate. The moderate rate of 6.0 lb N/1000 ft^2 has been found to be sufficient to provide acceptable visual turfgrass quality and color while maintaining a healthy, moderate growth rate. It is expected that the 4.0 lb N/1000 ft^2 rate will not provide acceptable visual turfgrass quality and color and that the 8.0 lb N/1000 ft^2 rate will result in excessive growth and potentially greater nitrate contamination than the other fertilizer rates.

In order to measure nitrate leaching below the rootzone, suction lysimeters were installed so the distal tip of the porous cup of each lysimeter was at a depth of 2.5 feet below the soil-thatch layer (approximately 0.6 inch deep). The lysimeters (constructed using high-flow ceramic cups and 2-inch diameter PVC pipe) were installed at a 45° angle so the lysimeter cup is below undisturbed soil. Twenty-four hours prior to each sampling day, a vacuum of approximately −40 KPa is applied to the lysimeters. Leachate is removed from the lysimeters using via vacuum, and samples are then acidified to pH 2, frozen, stored, and shipped via next-day air to the DANR Laboratory for NO_3^--N analysis by diffusion-conductivity analyzer.

Rounding out the "point-in-time" data from the lysimeters, measurements required to account for a hydrologic balance (including soil water content) and soil NO_3^--N measurements are being taken. The hydrologic balance is used to estimate the total NO_3^--N mass leached. Soil volumetric water content is determined weekly using time domain reflectometry (TDR) with four to eight sensors installed in null plots (plots within the research area which are not associated with any of the treatments). Soil NO_3^--N is determined at four rootzone depths: 0 to 12, 12 to 24, 24 to 36, and 36 to 48 inches below the soil-thatch layer (approximately 0.6 inches below the surface). Three cores are taken from each plot using a King Tube (i.d. 0.84-inch), cut and pooled by depth, dried at air temperature, sieved, and sent to the DANR Laboratory for NO_3^--N analysis by equilibrium extraction with KCl and diffusion-conductivity analyzer. Soil NO_3^--N provides a direct physical/chemical measurement of the movement (a layer) of NO_3^--N through the soil profile. It is useful for determining the accumulative effects over time.

Several additional measurements are being made throughout the course of the study. Visual turfgrass quality and color ratings are taken once every two weeks, in order to estimate plant performance and response to the N-fertility treatments. Also, clipping yield is taken weekly during four growth periods, with each period spanning four consecutive weeks and beginning one month following a N-fertility treatment application. The weekly clipping yields are dried and weighed to provide an estimate of plant growth for the previous 7 days. The four weekly yields within each growth period are then pooled by each plot and analyzed for total Kjeldahl nitrogen (TKN) analysis at the DANR Laboratory. With appropriate calculations, N uptake during the four 4-week growth periods is then determined. Finally, weather data is taken continuously from an on-site CIMIS station and a datalogger is installed at the research plot which is recording soil temperatures at the 4-inch depth.

When completed, this project will add to our current understanding of NO_3^- leaching from turfgrass (tall fescue in particular). The resulting BMPs will include the best way to fertilize tall fescue (rate and source) for optimal plant performance and N uptake while reducing the potential for NO_3^- contamination of groundwater. The BMPs have the potential to have a wide impact since they will be directly relevant to California home-lawn owners.

Review of Pesticide and Fertilizer Use in Turfgrass

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Turfgrass is a common component of many recreation areas, such as golf courses, recreation fields and parks and can also increase the esthetic value of homes and other property. Concerns and awareness of pesticide and fertilizer runoff and leaching have increased over the years and these concerns have lead to numerous studies focusing on the fates of these compounds. The use of pesticides and fertilizers is known to be essential for maintaining adequate turfgrass growth and aesthetic quality. These compounds can cause increased leaching into underground and surface waterways when applied inappropriately. Turfgrass can provide many benefits when maintained with appropriate care by using the best source, rate and timing of application of fertilizers and pesticides. Some of these benefits include: reduction of soil erosion, heat dissipation, noise abatement, glare reduction, air pollution control, and safe recreational surfaces (Beard and Green, 1994).

Nitrogen (N), phosphorus (P), and potassium (K) are the most commonly applied nutrients to turfgrass (Christians, 1998; Walker and Branham, 1992; Watschke, 1998). Nitrogen is applied in the greatest quantity of these three macro nutrients (Carrow, 1982; Christians, 1984; Snyder, 1984; Turner and Hummel, 1992). Many different forms and rates of nitrogen are applied to turfgrass. The source, rate and timing of pesticide and nitrogen fertilizer applications can affect the amount of runoff and leachate that is realized. The amount and type of nitrogen can also have an influence on the incidence of pest damage. This literature review was conducted to provide further insight on how the source, rate and timing of applications of pesticides and nitrogen effect the environment and the esthetic quality of turf.

Nitrogen Sources

Organic Nitrogen

There are natural and synthetic forms of organic N sources that can be used for turfgrass fertilization. The natural forms are those derived from plant or animal materials, whereas synthetics are chemically formed carbon containing compounds. Milorganite has been reported to be one of the oldest natural organic fertilizers (Christians, 1998). It is derived from sewage sludge that has been dried, heated and granulated. This fertilizer is said to be a non-burning slow-release source of N in order to minimize leaching and runoff (Milwaukee Metropolitan Sewerage District, 2002; Mitchell et al., 1978). Christians (1998) reported that synthetic organic nitrogen sources are the most commonly used form of N used on turfgrass.

Synthetic Organic Nitrogen

Urea is a commonly used form of nitrogen. It is water-soluble and can be organically or synthetically manufactured (Turner and Hummel, 1992). Urea is produced by combining atmospheric N with methane to form ammonia and carbon dioxide. Carbon dioxide and ammonia are combined under high temperatures to form urea. Urea contains one of the largest N concentrations with an N-P-K analysis of 45-0-0. Due to its high N concentration and its water solubility, it provides a quick high-concentration release of N which can lead to rapid greening, or if applied at high rates, possible foliage necrosis. Urea N can also be volatilized causing additional losses of N to the atmosphere. Studies have shown that volatilization losses can attribute up to 44.9% of applied urea (Bowman et al., 1987; Nelson et al., 1980; Titko et al., 1987; Torello et al., 1983; Volk, 1959). Similarly, Maggiotto et al. (2000) found that urea had the highest nitrous oxide losses during the drier season when compared to two other types of fertilizer.

To avoid the downfalls of urea, other forms of urea were developed. Ureaformaldehyde is a slowly soluble form of N and is mainly composed of urea linked by methylene groups (Goertz, 1993). This group of fertilizers is commonly used in turfgrass care due to its low potential for burning the foliage (Christians, 1998). Urea formaldehyde is mainly broken down by microbial decomposition (Christians, 1998; Harada et al., 1995). Isobutylidine diurea (IBDU) is another slowly soluble N fertilizer, but is mainly broken down by hydrolysis (Smith, 1995). This fertilizer can be useful where microbial decomposition can interfere with the rate at which the N is released, which can lead to decreased availability. Another urea-based fertilizer type is the sulfur coated ureas (SCU). SCUs are produced by applying a molten sulfur coating, then applying a wax and a flow conditioner onto urea (Harada et al., 1995; Turner and Hummel, 1992). Water enters through imperfections in the surface of the coating and urea is able to be released into the soil. This process makes SCU an effective way to slowly release nutrients into the soil, which has been shown to reduce N waste (Bowman and Peacock, 1996; Harada et al., 1995; Nus, 1994). Polymer coated ureas (PCU) are also available for use. They have a polymer coating surrounding the urea core and have a more regulated release of nutrients than SCUs (Christians, 1998; Harada et al., 1995). Their use in turf management is somewhat restricted by cost.

Inorganic Nitrogen Sources

Inorganic N sources contain a wide variety of nitrate and ammonia based fertilizers that are generally considered quick release (Carrow et al., 2001). One of the most widely used forms of inorganic nitrogen is ammonium nitrate (NH_4NO_3). Ammonium nitrate is water soluble and contains N sources that move slowly (ammonium) and move quickly (nitrate) through the soil (Carrow et al., 2001; Christians, 1989). Ammonium sulfate [$(NH_4)_2SO_4$] is another inorganic N source. It is also water soluble and the sulfur component can have an acidifying affect on the soil. Some inorganic N sources can provide other nutrients in addition to N. These sources include potassium nitrate (KNO_3), calcium nitrate [$Ca(NO_3)_2$] and the ammonium phosphates. These sources of nitrogen are often hygroscopic, which limits their use and often makes them difficult to apply during humid or damp periods (Christians, 1998).

Nitrogen Rates

There are many factors that need to be considered when determining the rate of applied fertilizers. The fertilizer type as discussed above is important so that only nutrients that are needed are applied, and that applications will not be detrimental to the environmental conditions at a specific site. Carrow et al. (2001) introduced several factors that should be considered when determining fertilizer rates, including: growth cycle of grass type, season, temperature, soil type, rainfall, irrigation, clipping removal, use, and quality expectations.

The growth cycle of the grass used can have an impact on the fate of N. The cool-season grasses may have a winter and/or summer dormancy depending on the location of the plot. Nitrogen applied during these dormancies can be lost from the soil column due to reduced and/or no uptake by the turfgrass. Warm-season grasses can also go through winter dormancy if planted in subtropical areas or in areas where the temperature drops below the minimum of 13 ºC (Carrow et al., 2001). Timing of N fertilizer application should generally correspond with the growth of both the root and shoot systems (Carrow et al., 2001).

How the turf is utilized can have an effect on the type and amount of N fertilizer applied. For example, application of N fertilizers for homeowners may be minimal depending on the amount of wear and tear their turf receives; whereas the usage on recreation areas, such as golf courses, may need to be carefully evaluated for best results. For instance, the tee on a golf course should be supplied with sufficient nutrients due to the heavy traffic (Walker and Branham, 1992). On the other hand, the fairway may not need more fertilizer than what is applied during establishment of the turf (Walker and Branham, 1992).

Turfgrass types and usage

There are a plethora of turfgrass choices. Turfgrass is typically differentiated into two major groups, warm-season turf and cool-season turf. Warm-season grasses have their highest period of nutrient need in the summer during the months of July, August, and September; whereas cool season grasses have their highest nutrient needs in the months of June, July, and October (Carrow et al., 2001). The main types planted in landscapes and used in turf research include bermudagrass, Kentucky bluegrass, St. Augustinegrass, ryegrass, tall fescue and creeping bentgrass.

Bermudagrass (*Cynodon* sp.) is a warm-season, fine textured grass that spreads by stolons and rhizomes. It has a prostrate growth habit. Bermudagrass has a relatively low water requirement and a low to high N requirement (Carrow et al., 2001). Bermudagrass is commonly used in the construction of golf greens, so it is frequently used in scientific studies examining the fates of nitrogen fertilizers (Brown et al., 1982; Cole et al., 1997; Sartain and Gooding, 2000; Snyder et al., 1984) and pesticides (Callahan et al., 1983; Duble et al., 1978a; Hong and Smith, 1997).

Kentucky bluegrass (*Poa pratensis*) is a cool-season turfgrass that is an extremely dense sod former having a vigorous rhizome system and is commonly found in home lawns and parks. Kentucky bluegrass has a high water requirement and a low to medium N requirement (Carrow et al., 2001). Its frequent use in the landscape has led to its use in many studies focusing on runoff (Krenitsky et al., 1998), N volatilization (Bowman et al., 1987; Mancino et al., 1988; Nelson et al., 1980; Starr and DeRoo, 1981; Titko, et al., 1987; Wesely et al., 1987), N leaching (Geron et al., 1993; Miltner et al., 1996; Mosdell and Schmidt, 1985; Nelson et al., 1980; Starr and DeRoo, 1981), and pesticide fates (Branham and Wehner, 1985; Goh et al., 1986; Gold et al., 1988; Horst et al., 1996).

St. Augustinegrass (*Stenotaphrum secundatum*) is a warm-season, coarse textured turfgrass that spreads by stolons. It has a prostrate growth habit. St. Augustine has a moderate water requirement and a low to medium N requirement (Carrow et al., 2001). It has been used in a study comparing turf and residential landscape plant nitrogen runoff and leaching (Erickson et al., 2001). This study found that St. Augustinegrass was able to colonize greater amounts of soil surface area in order to prevent leaching and runoff than a mixed species landscape planting.

Ryegrass (*Lolium perenne*) is a cool-season turfgrass with a bunch type growth habit. Ryegrass has a low to medium N requirement (Carrow et al., 2001). It has been used to look at surface runoff of pesticides and fertilizers (Linde et al., 1995), and stabilization of soil nitrate by reseeding after turf death (Bushoven et al., 2000).

Tall Fescue (*Festuca arundinacea*) is a cool-season coarse-textured turfgrass with a bunch type growth habit. Tall fescue has a relatively low water requirement and has a low to medium nitrogen requirement (Carrow et al., 2001). It is commonly used in low-water-use lawns and for erosion control. Studies have looked at runoff and sediment losses from tall fescue turf (Gross et al., 1991; Krenitsky, et al., 1998).

Creeping bentgrass (*Agrostis palustris*) is another common cool-season grass used in lawns and on golf putting greens. It has a stoloniferous growth habit. Bentgrass has a high relative water requirement and a low to high N requirement (Carrow et al., 2001). Bentgrass is such a regularly used turfgrass in landscape and recreation areas, so it has been used in many studies to investigate leaching of N from golf greens (Bowman et al., 1997; Mancino and Troll, 1990; Mitchell et al., 1978), surface runoff (Linde et al., 1995; Linde and Watschke, 1997), and pesticide movement (Gardner and Branham, 2001; Hong and Smith, 1997; Murphy et al., 1996; Smith and Bridges, 1996).

Nitrogen and Disease Interactions

Plants contain numerous compounds that utilize N. Nitrogen is used for proteins, plant growth substances, chlorophyll and many other metabolic and structural components. These components are also attractive to pests such as insects, pathogens, and nematodes. Nitrogen applications to turf can particularly affect disease susceptibility by affecting plant metabolic and morphological characteristics (Carrow et al., 2001; Madison, 1985). When high amounts of N is applied, the plant will respond with quick growth that results in thinner cell walls and more succulent tissues making it more susceptible to particular diseases such as brown patch (*Rhizoctonia* spp.), or Pythium blight (*Pythium* spp.) (Lucas, 1992). Not enough N can also result in disease problems. Low N levels can also make the plant more susceptible to diseases such as rust (*Puccinia* spp.), dollar spot (*Sclerotinia homecarpa*), and pink patch (*Limonomyces rosiepellis*) (Carrow et al., 2001; Lucas, 1992). The incidence of fungal diseases leads to the increase in the use of fungicides that could potentially leach or runoff into ground or surface water supplies.

Nitrogen Losses

There are five main ways that N can be lost, leaching, runoff, denitrification, volatilization, and clipping removal (Duble et al., 1978b; Street, 1982). These losses are not only wasteful, but they can lead to contamination of ground and surface waters. Losses of N can lead to eutrophication of water ways and contamination of drinking water above the drinking water standard set by the U.S. Public Health Service and the U.S. EPA of $10 mg \cdot L^{-1}$ NO_3-N (Petrovic, 1989; Spalding and Exner, 1993; Watschke et al., 1989). Nitrates in water sources have received more attention in recent years. Cantor et al. (1988) reported that possible adverse effects of nitrates in drinking water could include methemoglobinemia (blue baby syndrome), cancer and respiratory illness.

Nitrogen Leaching

Studies have shown that little leaching occurs when sandy soil plots were subjected to abundant amounts of nitrogen (approximately three to eight times the recommended application rate) and to heavy irrigation (Rieke and Ellis, 1974; Sheard et al., 1985; Synder et al., 1981). This suggests that there could be several factors affecting nitrogen leaching. Soil mobility has been thought to be one factor to influence leaching. This mobility makes nitrate the primary culprit in nitrogen leaching (Petrovic, 1990; Turner and Hummel, 1992; Waddington, 1985; Walker and Branham, 1992). Nitrogen leached into the ground and surface waters can lead to changes in the environment as well as cause problems in humans. It is well known that increased nitrogen levels in rivers and lakes can lead to eutrophication or even damage to the biota found in these waterways.

The amount of leaching can vary based on many different factors. Several factors reported include soil type, fertilizer source, fertilizer rate, temperature, rainfall, irrigation, relative humidity, and turf type (Petrovic, 1990; Rieke and Ellis, 1974). The range of leaching can vary from no leaching to losses of up to 84% (Brown et al., 1977; Nelson et al., 1980). The highest N leaching rates were found in ammonia nitrate fertilizer treatments (Brown et al., 1977, 1982; Snyder et al., 1984).

One of the most common recommendations for controlling leaching is to use soil-based media rather than sand-based media. Brown et al. (1982) presented evidence supporting this recommendation by comparing leachate concentrations from various rooting media planted with Tifdwarf bermudagrass overseeded with ryegrass, bluegrass, fescue and bentgrass. They found that the nitrate leachate concentrations were the greatest from the sand-based greens and the lowest from the soil-based greens. A soil amendment study conducted by Bigelow et al. (2001), found that nitrate leaching was greatest for non-amended sand and less for amended media.

The nitrate leaching of three cultivars of turfgrass were compared in a study by Liu et al. (1997). They found that nitrate concentrations in soil water varied among the different turfgrasses. Both tall fescue and perennial ryegrass had low potentials for nitrate leaching, whereas Kentucky bluegrass had a high nitrate leaching potential. This may be due to morphological differences among cultivars. Such as tall fescue has a deeper and bigger root system than Kentucky bluegrass (Beard, 1973; Liu et al., 1997; Turgeon, 1991).

Nitrogen Runoff

Runoff of nutrients has been associated with heavy rainfall or irrigation, poor soil infiltration rates and bare soils (Waddington, 1985). This runoff can then potentially enter into surface waters. Morton et al. (1988) conducted a study that only had two natural runoff events occur in 2 years. Runoff has also been shown to be difficult to produce in turfgrass even under simulated conditions. Gross et al. (1991) only found significant differences at simulated high rainfall intensities ($120 mm\cdot h^{-1}$) between bare ground and high density seeding ($488\ kg\cdot ha^{-1}$). Runoff losses were less after a 30-min simulated storm in plots with turfgrass ($\sim$10-60 $kg\cdot ha^{-1}$) as compared to bare soil plots (223 $kg \cdot ha^{-1}$). Many studies have shown that runoff from turfgrass is small (Gross et al., 1990; Morton et al., 1988; Petrovic, 1990). In a study conducted by Linde and Watschke (1997), they found that applying fertilizer on nearly saturated soils, prior to a rainfall event, resulted in runoff of nutrients. Brown et al. (1982) conducted a study where the sandy loam treatment had runoff concentrations of 30 $mg \cdot L^{-1}$ whereas no runoff was collected from sand or sandy loam soil mixtures.

Pesticide Losses

Like N fertilizers, pesticides are an integral part of a turfgrass management program (Watschke, 1986). Also, like fertilizers, pesticides can also be lost through leaching, runoff, and volatilization. Examples of the various pesticide types include herbicides, fungicides, and insecticides. Their components also present water quality issues and other concerns, such as surface residues. To put this problem in perspective, 0.07% of readings from golf courses for pesticides in groundwater samples were above health advisory levels or maximum contaminant levels (Cohen et al., 1997).

Herbicides are commonly used on turfgrass to control weeds such as crabgrass. Studies have been conducted and showed that the fastest degradation of herbicides occurred under conditions of sand-soil mix, high moisture, and temperatures of 25 to 30 ºC (Choi et al., 1988; Petrovic et al., ?). Murphy et al. (1996) investigated human exposure to volatilized and dislodgeable herbicide residues. Their study measured less than 1% of total applied MCPP was volatilized residue and found that by day five MCPP, dislodgeable residues where not detectible. Murray et al. (1983) found that there were only ppb quantities of herbicides in the soil a year after eight annual cycles of herbicide treatments.

Fungicides are used to control fungal pathogens on turfgrass. Liu et al. (1995) examined the efficacy of core cultivation before the application of fungicides. They found that core cultivation 1 d before resulted in the best results. The distribution, mobility and persistence of fungicides in turf, soil and thatch has been examined by numerous researchers (Dell et al., 1994; Fushtey and Frank, 1981; Gardner and Branham, 2001; Gardner et al., 2000; Rhodes and Long, 1974). These researches have found that the fungicides used have little movement (Gardner and Branham, 2001; Rhodes and Long, 1974), have little vertical distribution (30 to 60 cm) (Fushtey and Frank, 1981), and can be rapidly dissipated in turfgrass (Dell et al., 1994; Gardner et al., 2000). Murphy et al. (1996) reported that volatilization of the fungicide within the first 5 to 8 d accounted for less that 8% of losses.

Insecticides are commonly applied to turf in order to maintain an esthetically pleasing lawn. In the past, some of the insecticides used had long-term environmental effects (Randell, 1989). The pesticides today are short-lived and we also have the ability to detect the pesticides in the ppb (Branham, 1989). The fates of many of these insecticides, such as diazinon (Branham and Wehner, 1985; Kuhr and Tashiro, 1978), and isofenphos (Cisar and Snyder, 1996; Niemczyk, 1987) have been investigated and have found that little if any insecticides leached into the soil, even with additional irrigation. Conversely, Starrett et al. (1996) found that irrigation can have an impact on the movement in soil. Other studies have looked at the persistence and movement of compounds such as, diazinon (Sears and Chapman, 1979), chlorpyrifos (Horst et al., 1996), tichlorfon (Petrovic et al., ?), and isofenphos (Cisar and Snyder, 1996; Sears et al., 1987). Measurements of dislodgeable residues of various pesticides such as isozofos (Murphy et al., 1996), chlorphrifos (Goh et al., 1986), and diazinon (Sears et al., 1987), have shown that these pesticides showed little hazard to humans after 3 d.

Conclusion

Nitrogen leaching and runoff still contribute to ground and surface water pollution. Even though we better understand the problem at hand, due to numerous studies on the subject, more specific studies need to be conducted to look at specific problems. One of these problems is from homeowners not being educated on how much, what type and when to apply nitrogen fertilizers. Since many homes have lawns, this can lead to increases in the amount of N runoff and leaching that can reach surface and ground water. Studies conducted on turfgrass selection and nitrogen source rates for a specific region should be conducted in order to better advise homeowners and lawn care providers. This public knowledge could lead to better looking and more utilized lawns, less fertilizer and pesticide use, and improved environmental quality.

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Developing a Nitrate Leaching Hazard Index for Crop Production

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The University of California (UC) Center for Water Resources, based in Riverside, recently received a two-year Water Quality Program grant from the United States Department of Agriculture (USDA)-Cooperative State Research, Education, and Extension Service (CSREES) to develop a nitrate hazard index (HI) specific for irrigated agriculture in the Southwest states and to provide education and training to help advisors, consultants, and growers use the index to improve water quality.

The HI will assign a hazard value based on the leaching and denitrification potential of the soil, root system of the crop, and irrigation system(s) used. Computer models, such as NLEAP or ENVIRO-GRO will be used to validate the ranking method. The HI approach is intended to aid growers in assessing their management practices and identifying best management practices (BMPs) to reduce nitrate leaching.

Research is already underway to develop a reliable soil index and hazard scale. Since September 2003, the soil descriptions of more than 300 California soil series have been independently reviewed by three personnel at the UC Center for Water Resources. A hazard scale of 0-4 has been developed, with "4" meaning that the soil is among the most hazardous and "1" meaning the soil has a low hazard potential for nonpoint source nitrate pollution.

Laosheng Wu

Coarse textured soils with low organic matter content and no layers in the profile to restrict water movement are most sensitive to groundwater degradation by nitrate because of high transmission rates through their profile, high water infiltration rates, low denitrification potential, and high leaching. Clayey soils and soils with clay layers and textural discontinuities in the profile typically have slow water drainage, low leaching, and high denitrification potentials, resulting in a lower hazard value.

In addition to the California soils, research is progressing on listing and assigning HI to the Arizona and Nevada irrigated soil series. Preliminary evaluations of crops grown in the region are also underway.

Although several nitrogen indices have been developed to help growers assess nitrate leaching potential, none to date are applicable to irrigated agricultural lands found in the Southwest. Laosheng Wu, Extension Water Management Specialist, and Christine French, Water Quality Program Assistant, UC Center for Water Resources, are co-principal investigators on the project. Wu is California's Water Quality Coordinator for the USDA/CSREES Regional Water Quality Program for the Southwest States and Pacific Islands. Mainland states in the CSREES Regional Water Quality Program are California, Arizona, and Nevada.

Prior HI Recommendations

The concept of developing a nitrate HI in irrigated agriculture in California is not new but it has never been done before. Several years ago, the California State Water Resources Control Board (SWRCB) appointed a Nutrient Technical Advisory Committee (TAC) to develop recommendations for nutrient management associated with agricultural activities in California to meet water quality goals. In December 2002, the committee recommended the establishment of a nitrate hazard index (HI) for potential groundwater degradation, based on the irrigation system, soil, and crop(s) grown on a given field. The HI would have been used by growers as a self-assessment tool, but the TAC's recommendations were never implemented.

The Executive Summary of the TAC's final report stated, "The TAC recommends that all growers participate in a mandatory self assessment program to determine their potential risks of contributing to nutrient-related nonpoint source pollution and to develop a management plan to minimize their potential contribution to water quality degradation in California." The TAC's final report is available at *http://www.swrcb.ca.gov/nps/docs/tac_nutrient.doc.*

Addressing the practicality of assigning hazard values to California's agricultural soils and crops, the TAC wrote caveats in Section II of its final report, stating, "It is beyond the expertise or time commitment of the TAC to index the soils of the state" and to "classify all crops into [a] hazard index of 1, 2, or 3."

The research currently undertaken by Wu and French and their colleagues is the first study of its kind to implement the prior nutrient TAC recommendations for the development of a nitrate HI. A final report on the USDA-CSREES grant is due in September 2004.

November 2004

News from the UCR Turfgrass Program

Research Focus

Nitrogen Leaching from a Well-established Tall Fescue Turf

Objectives: 1) Evaluate annual N rate and source on tall fescue to determine which factor(s) optimize plant performance and N uptake while reducing the potential for nitrate (NO_3^-) leaching; 2) quantify the effect of N fertilizer rate and source on visual turfgrass quality and color, clipping yield, tissue N concentration, N uptake, concentration of NO_3^--N and NH_4^+-N in leachate at a depth below the rootzone, and concentration of NO_3^--N and NH_4^+-N in soil; and 3) develop BMPs for lawns under representative irrigation practices to optimize plant performance and N uptake while reducing the potential for NO_3^- leaching.

Treatments (13 total): No nitrogen check; ammonium nitrate, Polyon, Milorganite, and Nutralene each applied at an **annual** N rate of either 4.0, 6.0, or 8.0 lb/1000 ft^2. Annual N rate was divided into four equal applications on 1 May, 15 May, 15 Aug. and 15 Oct.

Measurements: Highlighted in objective 2. For a more complete description, please go to the publications section at the UCR Turf website at http://ucrturf.ucr.edu. There is a more in-depth article associated with this issue of News.

Duration of field study: 24 months, Oct. 2002 to Oct. 2004.

Findings:

Visual turfgrass quality ratings. This report covers data and analyses of visual turfgrass quality for 31 rating dates, taken from 6 Nov. 2002 to 30 Jan. 2004. In terms of overall analyses of 13 treatments, all but one fertilizer treatment were within range of an acceptable tall fescue lawn. This assumes that most people are satisfied with a tall fescue lawn when visual turfgrass quality is within the range of 5.5 to 6.5 (scale: 1 = worst, 5 = minimally acceptable, and 9 = best). Overall visual turfgrass quality ranged from 5.4 for Milorganite at an annual N rate of 4.0 lb/1000 ft^2 to 6.3 for ammonium nitrate at an annual N rate of 8.0 lb/1000 ft^2; the check treatment was 4.8. In terms of overall analysis of 12 fertilizer treatments, arranged in a 4×3 factorial design, ammonium nitrate and Polyon produced overall visual turfgrass quality of 6.0 while Milorganite and Nutralene produced a 5.7 (means significantly different). Also, annual N rates of 8.0, 6.0, and 4.0 lb/1000 ft^2 produced overall visual turfgrass quality of 6.1, 5.9, and 5.6, respectively (means significantly different). In terms of 31 rating dates, all but two fertilizer treatments resulted in a visual turfgrass quality rating $\geq$ 5.5 on 50% or more rating dates (exceptions were Milorganite and Nutralene at an annual N rate of 4.0 lb/1000 ft^2).

Fertilizer treatments that resulted in a visual turfgrass quality rating ≥ 6.0 on 50% or more rating dates included three N sources at an annual N rate of 8.0 lb/1000 ft^2 (ammonium nitrate, Nutralene, and Polyon) and two N sources at an annual N rate of 6.0 lb/1000 ft^2 (ammonium nitrate and Polyon).

Concentration of NO_3^--N in leachate. This report covers data and analyses of NO_3^--N concentrations in leachate on 33 sample dates from 9 Oct. 2002 to 4 Feb. 2004. These data were affected by a change in irrigation protocol on 2 July 2003. From 16 Oct. 2002 to 1 July 2003, the protocol was (100% ET_{crop}/DU) minus rainfall, based on the previous 7 d cumulative ET_o. Though visual ratings were not affected, this protocol caused some dry soil conditions. To alleviate this situation we decided to fall back on our historical knowledge of maintaining tall fescue during the summer in Riverside; that is 110% ET_o, based on the previous 7 day cumulative ET_o. Thus, we initiated this new irrigation protocol on 2 July 2003 which continued to the end of the field study. During minimalist irrigation from 16 Oct. 2002 to 1 July 2003, NO_3^--N concentrations in leachate were low (< 1 ppm) and differences among fertilizer treatments were basically not significant. Please note that the EPA Maximum Contaminant Level (MCL) for nitrates in drinking water is 10 ppm. It should be noted that the average NO_3^--N concentration of irrigation water was 4.2 ppm. During well-watered irrigation from 2 July 2003 to 4 Feb. 2004, NO_3^--N concentration in leachate was higher than the previous period. However, concentrations are probably not problematic except for one fertilizer treatment: ammonium nitrate at an annual N rate of 8.0 lb/1000 ft^2 (four applications at an N rate of 2.0 lb/1000 ft^2). On several sample dates, NO_3^--N concentration in leachate exceeded 10 ppm. Data also showed significant N source and rate effects on concentration of NO_3^--N in leachate. Basically, ammonium nitrate and the annual N rate of 8.0 lb/1000 ft^2 resulted in the highest concentrations of NO_3^--N in leachate.

These data concerning nitrate leaching, from a well-established tall fescue, will help support BMPs for fertilizing tall fescue lawns to optimize plant performance and nitrogen uptake while reducing the potential for nitrate leaching. Several preliminary observations follow.

1. Minimalist irrigation reduces the potential for nitrate leaching. However, sufficient irrigation is needed to promote healthy turfgrass.

2. An annual N rate of 4.0 to 6.0 lb/1000 ft^2 produces an acceptable to good quality tall fescue lawn. Higher rates are not necessary and increase the risk of nitrate leaching.

3. Slow-release N sources (Nutralene, Milorganite, and Polyon) cause less nitrate leaching than a fast-release N source (ammonium nitrate).

4. The amount of nitrate leaching from a fast-release N source can be drastically reduced if N rates of individual applications do not exceed 1.0-1.5 lb/1000 ft^2.

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VOLUMES 8.1 and 8.2

COOPERATIVE EXTENSION UNIVERSITY OF CALIFORNIA

CO-HORT

Development of BMPs for Fertilizing Tall Fescue

by
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The problem addressed by this project is potential nitrate (NO_3^--N) contamination of groundwater caused by fertilization of the approximate 679,426 acres of residential yards in California. On a statewide basis, residential yards are the largest component of urban landscapes and lawns are the largest component of residential yards. Thus, a project involving the development of best management practices (BMPs) for fertilizing lawns to optimize plant performance and nitrogen (N) uptake while reducing the potential for NO_3^--N leaching focuses on a potential urban source of NO_3^--N contamination of groundwater. Since the project involves research sites in southern and northern California and will be on tall fescue, the most widely used lawngrass in California, the impact of this project will be on a statewide basis.

Petrovic prepared a review paper entitled "The fate of nitrogenous fertilizers applied to turfgrass." He summarized 11 papers on NO_3^--N leaching from fertilizers applied to turfgrass. He concluded that leaching of fertilizer N applied to turfgrass has been shown to be highly influenced by: soil texture; N source, rate, and timing; and irrigation and rainfall. If a significantly higher than normal rate of a soluble N source is applied to a sandy turfgrass site that is highly irrigated, significant NO_3^--N leaching could occur. However, limiting irrigation to only replace moisture used by the plant, using slow-release N sources, and using less sandy soils will significantly reduce or eliminate NO_3^--N leaching from turfgrass sites. Other research has shown that there is a negligible chance of NO_3^--N leaching from turfgrass. However, these findings are normally conditional as follows: water soluble fertilizers are not applied in excess; sandy soils are not heavily irrigated; turfgrass is well maintained using standard agronomic practices including judicious use of fertilizers and irrigation; the turfgrass is not immature and the soil is not disturbed such as during establishment; and root absorption is not low because of dormancy, stress, or because of unhealthy turfgrass. In reality, home-lawn owners may cause NO_3^--N contamination of groundwater because they do not meet all the conditions that are required to not cause NO_3^--N contamination of groundwater.

This project will add to our current understanding of NO_3^--N leaching from turfgrass because we have not been able to find much work with tall fescue. Therefore, the information will be new, especially determining the best way to fertilize tall fescue grown in California for optimal plant performance and N uptake while reducing the potential for NO_3^--N contamination of groundwater.

OBJECTIVES

The objectives of the research project are to 1) evaluate the annual N rate and source on tall fescue to determine which treatments optimize plant performance and N uptake while reducing the potential for NO_3^--N leaching 2) quantify the effect of N fertilizer rate and source on: visual turfgrass quality and color; clipping yield, concentration of N in clipping tissue, and N uptake; concentration of NO_3^--N and NH_4^+-N in leachate at a depth below the rootzone; and concentration of NO_3^--N and NH_4^+-N in soil 3) develop BMPs for lawns under representative irrigation practices to optimize plant performance and N uptake while reducing the potential for NO_3^--N leaching and 4) conduct outreach activities, including oral presentations and trade journal publications, emphasizing the importance of the BMPs and how to carry out these practices for N fertilization of lawns.

DESCRIPTION

The project is being conducted at two sites with different climates and turfgrass maturity, but which are being maintained similarly. One site is a newly established tall fescue plot (sodded late Sept. 2002) in northern California at UC Davis and the other is a mature tall fescue plot (seeded Apr. 1996) in southern California at UC Riverside. Both sites were established to tall fescue, since it is the most widely used lawngrass in California, especially for urban landscapes. The plots at both sites are being irrigated at 110% CIMIS ET_o (California Irrigation Management and Irrigation System), with the amount of irrigation determined weekly based on the previous 7-day cumulative CIMIS ET_o (rainfall may cause the cancellation of irrigation events). There are three irrigation events per week, which are cycled to prevent runoff. The experimental design at both sites is a randomized complete block (RCB) with N treatments arranged in a 4×3 factorial (four N sources and three rates) (Table 1). A no-nitrogen check treatment is also included to allow for additional statistical comparisons. Therefore, there are 13 treatments which include 12 fertilizer treatments and a check treatment. Nitrogen treatments are being applied from 15 Oct. 2002 to 15 Aug. 2004 at UC Riverside and from 15 May 2003 to 15 Oct. 2005 at UC Davis.

During the 24-month field phase of this study, several measurements are being collected, including visual ratings, NO_3^--N and NH_4^+-N concentrations of soil water below the rootzone, and others (Table 2). Measurements are being taken from Oct. 2002 to Oct. 2004 at UC Riverside and from Dec. 2003 to Nov. 2005 at UC Davis.

Table 1. Protocol for 13 treatments for the tall fescue BMP fertilization study.

Date of application	N source[z] (N-P_2O_5-K_2O)	Rate (lb N/1000 ft^2) a	b	c
1 Mar.	No nitrogen check	0.0	0.0	0.0
	A. Ammonium nitrate 34-0-0	1.0	1.5	2.0
	B. Polyon 43-0-0	1.0	1.5	2.0
	C. Milorganite 6-2-0	1.0	1.5	2.0
	D. Nutralene 40-0-0	1.0	1.5	2.0
15 May	No nitrogen check	0.0	0.0	0.0
	A. Ammonium nitrate 34-0-0	1.0	1.5	2.0
	B. Polyon 42-0-0	1.0	1.5	2.0
	C. Milorganite 6-2-0	1.0	1.5	2.0
	D. Nutralene 40-0-0	1.0	1.5	2.0
15 Aug.	No nitrogen check	0.0	0.0	0.0
	A. Ammonium nitrate 34-0-0	1.0	1.5	2.0
	B. Polyon 42-0-0	1.0	1.5	2.0
	C. Milorganite 6-2-0	1.0	1.5	2.0
	D. Nutralene 40-0-0	1.0	1.5	2.0
15 Oct.	No nitrogen check	0.0	0.0	0.0
	A. Ammonium nitrate 34-0-0	1.0	1.5	2.0
	B. Polyon 43-0-0	1.0	1.5	2.0
	C. Milorganite 6-2-0	1.0	1.5	2.0
	D. Nutralene 40-0-0	1.0	1.5	2.0
Total	No nitrogen check	0.0	0.0	0.0
	A. Ammonium nitrate 34-0-0	4.0	6.0	8.0
	B. Polyon 43-0-0 and 42-0-0	4.0	6.0	8.0
	C. Milorganite 6-2-0	4.0	6.0	8.0
	D. Nutralene 40-0-0	4.0	6.0	8.0

[z] Ammonium nitrate is a fast-release, water soluble N source; Polyon is a slow-release, polymer-coated N source; Milorganite is a slow-release, natural organic N source; and Nutralene is a slow-release, water insoluble, methylene ureas N source.

Note: Potassium sulfate (0-0-50) and treble superphosphate (0-45-0) will be applied to all plots at an annual rate of 4.0 lb K_2O/1000 ft^2 and 3.0 lb P_2O_5/1000 ft^2.

RESULTS AND DISCUSSION

UC Riverside

This report briefly covers three important measurements that are being taken during this study: visual turfgrass quality ratings, concentration of NO_3^--N in leachate, and concentration of NO_3^--N and NH_4^+-N in soil.

Visual turfgrass quality ratings

Visual turfgrass quality ratings measure appear-

Table 2. Protocol for measurements collected during the tall fescue BMP fertilization study.

Measurement	Frequency	Method and other comments
1. Visual turfgrass quality	Once every 2 weeks	1 to 9 scale, with 1 = worst quality, 5 = minimally acceptable quality, and 9 = best quality for tall fescue
2. Visual turfgrass color	Same time as turfgrass quality	1 to 9 scale, with 1 = worst color (brown), 5 = minimally acceptable color, and 9 = best color (dark green) for tall fescue
3. Clipping yield, TKN, and N uptake	Four growth periods, with each period spanning four consecutive weekly clipping yields. All periods start one month following each of the four N-fertility treatment application dates (Table 1). Generally, periods are: 1 Apr. to 30 Apr.; 15 June to 15 July; 15 Sept. to 15 Oct.; and 15 Nov. to 15 Dec.	Weekly clipping yield, representing 7-day growth, is collected from 9.2 ft^2 (26% of the total surface area) from each plot with the same mower used for routine mowing, except a specially constructed collection box is attached to the mower. Weekly clipping yields are dried at 60 to 67 °C in a forced-air oven for 48 hours and immediately weighed. Yield reported as $g \cdot m^{-2}$. The four weekly yields within each growth period are pooled by the 52 plots and ground. TKN analysis is conducted at the DANR laboratory located at UC Davis. With appropriate calculations, N uptake during four 4-week growth periods is determined.
4. NO_3^--N and NH_4^+-N concentration of soil water below root-zone	Once every 2 weeks	One suction plate lysimeter was installed in each plot so the distal tip of the lysimeter cup is at a depth of 2.5 ft below the soil-thatch layer (approximately 0.6 inch deep). The lysimeters were installed at a 45° angle so the lysimeter cup is below undisturbed soil. They were constructed using high-flow ceramic cups (round bottom neck top cups, 1.9-inch diameter, Soil Moisture Equipment Corp. catalog number 653X01-B01M3) and 2-inch diameter PVC pipe. A vacuum of approximately –40 KPa is applied to the lysimeters 24 h before the leachate sampling day. Samples are acidified to pH 2.4-2.8, frozen, and stored until shipped via next-day air to the DANR Laboratory, then stored at 4 °C until analyzed for NO_3^--N and NH_4^+-N by flow injection analyzer method. Analysis occurs within 28 days of leachate collection.
5. Soil water content	Once every 7 days	Volumetric soil water content is determined from the 0- to 48-inch soil depth zone at the same time each Wednesday using four time domain reflectometry (TDR) sensors (MoisturePoint MP-917 TDR unit with Type 2 probe) installed in four null plots within the research plot. The most recent irrigation event is on Tuesday mornings.
6. NO_3^--N and NH_4^+-N concentration in soil	Beginning of study (20 Dec. 2002) and at 12 months (1 Oct. 2003) and 24 months (1 Oct. 2004) after initial fertilizer treatments	Two soil cores are taken from each plot and separated into two soil depth zones for the initial sampling: 0 to 12 inches and 12 to 30 inches. For the second and third sampling, cores are separated into three soil depth zones: 0 to 12 inches, 12 to 24 inches, and 24 to 36 inches. A grid is used to ensure that no part of the plot is sampled more than once for the duration of the study. Cores from each plot are pooled by depth; 6 g soil from each plot and depth zone is immediately placed in 40 ml of 2 M KCl to begin the extraction process. Standard procedures are followed to determine NO_3^--N and NH_4^+-N concentration on a dry soil basis.
7. Weather data	Continuous	Data obtained from a CIMIS station located at the UCR Turfgrass Research Project. Soil-temperature data loggers also are installed on the research plot.
8. Statistical procedures (to date)		Most measured variables are statistically analyzed according to a RCB design with 12 treatments arranged in a 4×3 factorial. When the no-nitrogen check treatment is included, a RCB design is used to analyze all 13 treatments. Overall analyses involved a repeated measures design, with measurement date as the repeated measures factor.

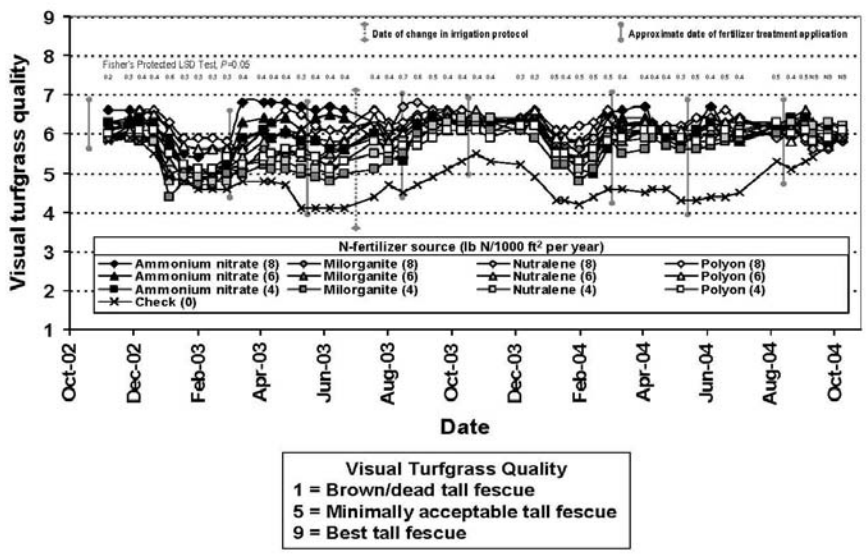
ance based on several characteristics that normally include color, texture (leaf width and length), uniformity, and density. It should be noted that each characteristic also can be rated by visual means.

This report covers data and analyses of visual turfgrass quality for 48 rating dates, taken from 6 Nov. 2002 to 8 Oct. 2004 (Fig. 1).

In terms of overall analyses of 13 treatments, all fertilizer treatments were within range of an acceptable tall fescue lawn. This assumes that most people are satisfied with a tall fescue lawn when visual turfgrass quality is within the range of 5.5 to 6.5 (1 to 9 scale, with 1 = worst, 5 = minimally acceptable, and 9 = best tall fescue). Overall visual turfgrass quality ranged from 5.5 for Milorganite at an annual N rate of 4.0 lb/1000 ft^2 to 6.2 for ammonium nitrate and Polyon at an annual N rate of 8.0 lb/1000 ft^2; the check treatment was 4.8.

In terms of overall analyses of 12 fertilizer treatments, arranged in a 4×3 factorial design, ammonium nitrate and Polyon produced overall visual turfgrass quality of 6.0 while Milorganite and Nutralene produced 5.8 and 5.9, respectively. Also, annual N rates of 8, 6, and 4 lb/1000 ft^2 produced overall visual turfgrass quality of 6.1, 5.9, and 5.7, respectively.

Figure 1. The effect of 13 treatments on visual turfgrass quality of tall fescue from 6 Nov. 2002 to 8 Oct. 2004.



In terms of 48 rating dates, all fertilizer treatments resulted in a visual turfgrass quality rating ≥ 5.5 on 50% or more rating dates. Fertilizer treatments that resulted in a visual turfgrass quality rating ≥ 6.0 on 50% or more rating dates included all fertilizer sources at the annual N rate of 8.0 lb/1000 ft^2; all fertilizer sources at the annual N rate of 6.0

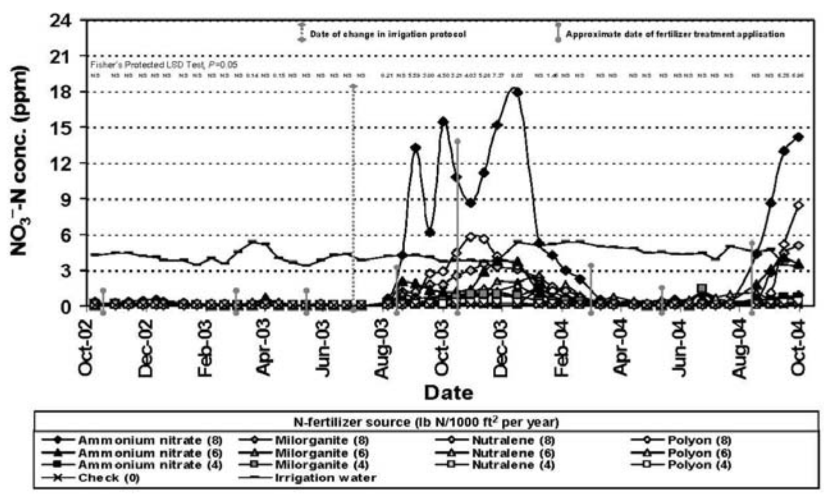
lb/1000 ft^2, except for Nutralene; and only one fertilizer source (ammonium nitrate) at the annual N rate of 4.0 lb/1000 ft^2.

Concentration of NO_3^--N in leachate

Data for NO_3^--N concentrations in leachate on 48 sample dates from 9 Oct. 2002 to 29 Sept. 2004 are shown in Fig. 2.

These data were affected by a change in irrigation protocol on 2 July 2003. From 16 Oct. 2002 to 1 July 2003, the protocol was (100% ET_{crop}/DU) minus rainfall, based on the previous 7-day cumulative CIMIS ET_o. The goal of this protocol was to irrigate according to plant water use needs and not to over-irrigate nor under-irrigate. However, we gradually realized that in making up rainfall, we may have caused some dry soil conditions, especially in the 0- to 6-inch soil depth zone. However, visual drought symptoms were not apparent on all dates, when visual turfgrass quality and color ratings were taken. To alleviate this situation of trying to micromanage a plot that was maintained on the "edge" in terms of plant water use and soil water depletion, we decided to fall back on our historical knowledge of maintaining tall fescue during the summer in Riverside; that is 110% CIMIS ET_o, based on the previous 7-day cumulative CIMIS ET_o. Thus, we initiated the new irrigation protocol on 2 July 2003 and continued it until the end of the field study which was 12 Oct. 2004.

Figure 2. The effect of 13 treatments on NO_3^--N concentration in leachate from 9 Oct. 2002 to 29 Sept. 2004.



During minimalist irrigation from 16 Oct. 2002 to 1 July 2003, NO_3^--N concentrations in leachate were low (< 1 ppm) and differences among treatments were basically not significant. It should be noted that the average NO_3^--N concentration of irrigation water was 4.3 ppm.

During well-watered irrigation from 2 July 2003 to 29 Sept. 2004, NO_3^--N concentration in leachate was higher than the previous period. However, concentrations are probably not problematic except for one fertilizer treatment: ammonium nitrate at an annual N rate of 8.0 lb/1000 ft^2 (four applications at a N rate of 2.0 lb/1000 ft^2). On several sample dates during the months of September through December, NO_3^--N concentration in leachate exceeded 10 ppm. Data also showed significant N source and N rate effects on concentration of NO_3^--N in leachate. Basically, ammonium nitrate and the annual N rate of 8.0 lb/1000 ft^2 resulted in the highest concentrations of NO_3^--N in leachate.

These data concerning nitrate leaching, from a well-established tall fescue, will help support BMPs for fertilizing tall fescue lawns to optimize plant performance and nitrogen uptake while reducing the potential for nitrate leaching. Listed below are several observations.

1. Minimalist irrigation reduces the potential for nitrate leaching. However, sufficient irrigation is needed to promote healthy turfgrass.
2. An annual N rate of 4 to 6 lb/1000 ft^2 produces an acceptable to good quality tall fescue lawn. Higher rates are normally not necessary and may increase the risk of nitrate leaching.
3. Slow-release N sources (Nutralene, Milorganite, and Polyon) cause less nitrate leaching than a fast-release N source (ammonium nitrate).
4. The amount of nitrate leaching from a fast-release N source can be drastically reduced if N rates of individual applications do not exceed 1.0 to 1.5 lb/1000 ft^2.

Concentration of NO_3^--N and NH_4^+-N in soil

During the beginning of the study (20 Dec. 2002), NO_3^--N concentrations were low (< 1 ppm), fairly uniform across the plots, and slightly higher in the 12- to 30-inch soil depth zone than the 0- to 12-inch soil depth zone. Also, NH_4^+-N concentrations were low (< 1 ppm) and slightly higher in the 0- to 12-inch soil depth zone than the 12- to 30-inch soil depth zone.

During 1 year following fertilizer treatment applications (9 Oct. 2003), NO_3^--N concentrations were low (< 2 ppm) and significantly affected by the 13 treatments but not the three soil depth zones (0 to 12 inches,12 to 24 inches, and 24 to 36 inches). Also, NH_4^+-N concentrations were low (normally < 2 ppm) and not significantly affected by the 13 treatments but significantly affected by the three soil depth zones; NH_4^+-N soil concentrations were highest at the 0- to 12-inch soil depth zone.

During 2 years following fertilizer treatment applications (6 Oct. 2004), NO_3^--N concentrations were low (< 2 ppm) and significantly affected by the 13 treatments and the three soil depth zones. Also, NH_4^+-N concentrations were low (< 2 ppm) and not significantly affected by the 13 treatments but significantly affected by the three soil depth zones; NH_4^+-N soil concentrations were highest at the 0- to 12-inch soil depth zone.

UC Davis

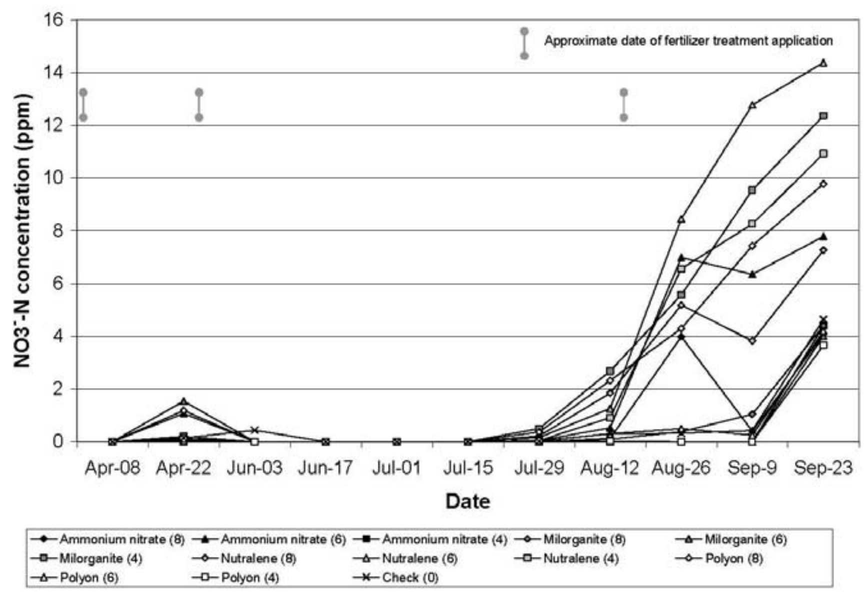
This report briefly describes the results we obtained during 2005. As in 2004 and even with prophylactic fungicide applications, *Rhizoctonia* brown patch infested much of the experimental turfgrass plot area during the early- and mid-summer months. This along with an uneven fertilizer treatment application in May 2005 prevented worthwhile color and quality evaluations. Therefore, our focus was on the regular and routine collection of soil water leachate samples for the analysis of NO_3^--N.

Concentration of NO_3^--N in leachate

Data from NO_3^--N concentrations in leachate on 11 sample dates from 8 Apr. to 23 Sept. 2005 are shown in Figure 3.

During this time period, the plots were irrigated using 110% CIMIS ET_o values obtained from a local weather station. Weekly application rates were based on the previous 7-day cumulative CIMIS ET_o values. NO_3^--N concentrations stayed low (under 2 ppm) from April to early August. A slight rise in April in response to the March fertilization was noted. In early August and in advance of the 16 Aug. fertilizer applications, leachate NO_3^--N concentrations began to increase. By mid-to-late September, several treatments had leachate NO_3^--N concentrations near or above 10 ppm. These included: Nutralene (annual N rate of 4.0, 6.0, and 8.0 lb/1000 ft^2, Milorganite (annual N rate of 4.0 lb/1000 ft^2), Polyon (annual N rate of 8.0 lb/1000 ft^2) and ammonium nitrate (annual N rate of 6.0 lb/1000 ft^2). Unlike the results at UC Riverside, the highest rate of ammonium nitrate (annual N rate of 8.0 lb/1000 ft^2) did not result in high concentrations of NO_3^--N in the leachate. The NO_3^--N concentration of the irrigation water was always below 1 ppm, except for the 23 Sept. analysis when it was 3.2 ppm.

Figure 3. The effect of 13 treatments on NO_3^--N concentrations in leachate at UC Davis from 8 Apr. to 23 Sept. 2005.



The high NO_3^--N in the leachate from the slow-release fertilizers (Nutralene and Polyon) is of concern. This result was not seen at UC Riverside and will be followed closely at UC Davis until the end of the project (late 2005).

Thanks are given to the California Department of Food and Agriculture, Fertilizer Research and Education Program (CDFA FREP) for funding this project. Thanks are also given to other researchers involved in this study who include Amber Bruno, Alberto Chavez, Melody Meyer, and John Jacobsen. This paper was adapted from a paper published in the Proceedings of the 13th Annual, CDFA FREP Conference, Nov. 30, 2005, Salinas, California, p. 8-13.

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For more information about turfgrasses in California, please see http://ucrturf.ucr.edu.

Winter weeds in turf and ornamentals

by

Milt McGiffen

For much of California there is a noticeable change from summer to fall. Within a few weeks, temperatures may change from highs in the 100's to pleasant 70's. Plant species are generally adapted for optimal growth in a specific temperature range. You may start to notice that nutsedge and Bermudagrass that were growing furiously now seem to be standing still. Weed control programs have to reflect the change in weed emergence and growth. The summer weed control programs that were in place for nutsedge or crabgrass would now do little good and should be discontinued until temperatures warm again in the spring. You will begin to notice many of the winter weeds begin to appear, such as: malva, groundsel, London rocket and other mustards, stinging nettle, pineapple weed, prickly lettuce, and sowthistle.

Hand weeding and mulches are always standard weed control methods to fall back on. Chemical controls vary with the turf or ornamental species.

For more control information, check the University of California IPM program website: http:www.ipm.ucdavis.edu/PMG/selectnewpest.landscape.html